JURASSIC

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1 Main Page

The JUelich RApid Spectral SImulation Code (JURASSIC) is a fast radiative transfer model for the mid-infrared spectral region.This reference manual provides information on the algorithms and data structures used in the code. Further information can be found at: `http://www.fz-juelich.de/ias/jsc/jurassic`

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2.1 Data Structures

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4 Data Structure Documentation

4.1 atm_t Struct Reference

Atmospheric data.

```
#include <jurassic.h>
```

Data Fields

- int np
  Number of data points.
- double time [NP]
  Time (seconds since 2000-01-01T00:00Z).
- double z [NP]
  Altitude [km].
- double lon [NP]
  Longitude [deg].
- double lat [NP]
  Latitude [deg].
- double p [NP]

  Pressure [hPa].
- double t [NP]

  Temperature [K].
- double q [NG][NP]

  Volume mixing ratio.
- double k [NW][NP]

  Extinction [1/km].

4.1.1 Detailed Description

Atmospheric data.

Definition at line 206 of file jurassic.h.

4.1.2 Field Documentation

4.1.2.1 int atm_t::np

Number of data points.

Definition at line 209 of file jurassic.h.

4.1.2.2 double atm_t::time[NP]

Time (seconds since 2000-01-01T00:00Z).

Definition at line 212 of file jurassic.h.

4.1.2.3 double atm_t::z[NP]

Altitude [km].

Definition at line 215 of file jurassic.h.

4.1.2.4 double atm_t::lon[NP]

Longitude [deg].

Definition at line 218 of file jurassic.h.

4.1.2.5 double atm_t::lat[NP]

Latitude [deg].

Definition at line 221 of file jurassic.h.

4.1.2.6 double atm_t::p[NP]

Pressure [hPa].

Definition at line 224 of file jurassic.h.

4.1.2.7 double atm_t::t[NP]

Temperature [K].

Definition at line 227 of file jurassic.h.

4.1.2.8 double atm_t::q[NG][NP]

Volume mixing ratio.

Definition at line 230 of file jurassic.h.

4.1.2.9 double atm_t::k[NW][NP]

Extinction [1/km].

Definition at line 233 of file jurassic.h.

The documentation for this struct was generated from the following file:

- jurassic.h

4.2 ctl_t Struct Reference

Forward model control parameters.

```
#include <jurassic.h>
```

Data Fields

- int ng

  Number of emitters.
- char emitter [NG][LEN]

  Name of each emitter.
- int nd

  Number of radiance channels.
- int nw

  Number of spectral windows.
- double nu [ND]

  Centroid wavenumber of each channel [cm^-1].
- int window [ND]

  Window index of each channel.
- char tblbase [LEN]

  Basename for table files and filter function files.
- double hydz

  Reference height for hydrostatic pressure profile (-999 to skip) [km].
- int ctm_co2

  Compute CO2 continuum (0=no, 1=yes).
- int ctm_h2o

  Compute H2O continuum (0=no, 1=yes).

- int ctm_n2

  Compute N2 continuum (0=no, 1=yes).
- int ctm_o2

  Compute O2 continuum (0=no, 1=yes).
- int refrac

  Take into account refractivity (0=no, 1=yes).
- double rayds

  Maximum step length for raytracing [km].
- double raydz

  Vertical step length for raytracing [km].
- char fov [LEN]

  Field-of-view data file.
- double retp_zmin

  Minimum altitude for pressure retrieval [km].
- double retp_zmax

  Maximum altitude for pressure retrieval [km].
- double rett_zmin

  Minimum altitude for temperature retrieval [km].
- double rett_zmax

  Maximum altitude for temperature retrieval [km].
- double retq_zmin [NG]

  Minimum altitude for volume mixing ratio retrieval [km].
- double retq_zmax [NG]

  Maximum altitude for volume mixing ratio retrieval [km].
- double retk_zmin [NW]

  Minimum altitude for extinction retrieval [km].
- double retk_zmax [NW]

  Maximum altitude for extinction retrieval [km].
- int write_bbt

  Use brightness temperature instead of radiance (0=no, 1=yes).
- int write_matrix

  Write matrix file (0=no, 1=yes).

4.2.1 Detailed Description

Forward model control parameters.

Definition at line 238 of file jurassic.h.

4.2.2 Field Documentation

4.2.2.1 int ctl_t::ng

Number of emitters.

Definition at line 241 of file jurassic.h.

4.2.2.2 char ctl_t::emitter[NG][LEN]

Name of each emitter.

Definition at line 244 of file jurassic.h.

4.2.2.3 int ctl_t::nd

Number of radiance channels.

Definition at line 247 of file jurassic.h.

4.2.2.4 int ctl_t::nw

Number of spectral windows.

Definition at line 250 of file jurassic.h.

4.2.2.5 double ctl_t::nu[ND]

Centroid wavenumber of each channel [cm^-1].

Definition at line 253 of file jurassic.h.

4.2.2.6 int ctl_t::window[ND]

Window index of each channel.

Definition at line 256 of file jurassic.h.

4.2.2.7 char ctl_t::tblbase[LEN]

Basename for table files and filter function files.

Definition at line 259 of file jurassic.h.

4.2.2.8 double ctl_t::hydz

Reference height for hydrostatic pressure profile (-999 to skip) [km].

Definition at line 262 of file jurassic.h.

4.2.2.9 int ctl_t::ctm_co2

Compute CO2 continuum (0=no, 1=yes).

Definition at line 265 of file jurassic.h.

4.2.2.10 int ctl_t::ctm_h2o

Compute H2O continuum (0=no, 1=yes).

Definition at line 268 of file jurassic.h.

4.2.2.11 int ctl_t::ctm_n2

Compute N2 continuum (0=no, 1=yes).

Definition at line 271 of file jurassic.h.

4.2.2.12 int ctl_t::ctm_o2

Compute O2 continuum (0=no, 1=yes).

Definition at line 274 of file jurassic.h.

4.2.2.13 int ctl_t::refrac

Take into account refractivity (0=no, 1=yes).

Definition at line 277 of file jurassic.h.

4.2.2.14 double ctl_t::rayds

Maximum step length for raytracing [km].

Definition at line 280 of file jurassic.h.

4.2.2.15 double ctl_t::raydz

Vertical step length for raytracing [km].

Definition at line 283 of file jurassic.h.

4.2.2.16 char ctl_t::fov[LEN]

Field-of-view data file.

Definition at line 286 of file jurassic.h.

4.2.2.17 double ctl_t::retp_zmin

Minimum altitude for pressure retrieval [km].

Definition at line 289 of file jurassic.h.

4.2.2.18 double ctl_t::retp_zmax

Maximum altitude for pressure retrieval [km].

Definition at line 292 of file jurassic.h.

4.2.2.19 double ctl_t::rett_zmin

Minimum altitude for temperature retrieval [km].

Definition at line 295 of file jurassic.h.

4.2.2.20 double ctl_t::rett_zmax

Maximum altitude for temperature retrieval [km].

Definition at line 298 of file jurassic.h.

4.2.2.21 double ctl_t::retq_zmin[NG]

Minimum altitude for volume mixing ratio retrieval [km].

Definition at line 301 of file jurassic.h.

4.2.2.22 double ctl_t::retq_zmax[NG]

Maximum altitude for volume mixing ratio retrieval [km].

Definition at line 304 of file jurassic.h.

4.2.2.23 double ctl_t::retk_zmin[NW]

Minimum altitude for extinction retrieval [km].

Definition at line 307 of file jurassic.h.

4.2.2.24 double ctl_t::retk_zmax[NW]

Maximum altitude for extinction retrieval [km].

Definition at line 310 of file jurassic.h.

4.2.2.25 int ctl_t::write_bbt

Use brightness temperature instead of radiance (0=no, 1=yes).

Definition at line 313 of file jurassic.h.

4.2.2.26 int ctl_t::write_matrix

Write matrix file (0=no, 1=yes).

Definition at line 316 of file jurassic.h.

The documentation for this struct was generated from the following file:

- jurassic.h

4.3 los_t Struct Reference

Line-of-sight data.

```
#include <jurassic.h>
```

Data Fields

- int np

    Number of LOS points.
- double z [NLOS]

    Altitude [km].
- double lon [NLOS]

    Longitude [deg].
- double lat [NLOS]

    Latitude [deg].
- double p [NLOS]

    Pressure [hPa].
- double t [NLOS]

    Temperature [K].
- double q [NG][NLOS]

    Volume mixing ratio.
- double k [NW][NLOS]

    Extinction [1/km].
- double tsurf

    Surface temperature [K].
- double ds [NLOS]

    Segment length [km].
- double u [NG][NLOS]

    Column density [molecules/cm^ 2].

4.3.1 Detailed Description

Line-of-sight data.

Definition at line 321 of file jurassic.h.

4.3.2 Field Documentation

4.3.2.1 int los_t::np

Number of LOS points.

Definition at line 324 of file jurassic.h.

4.3.2.2 double los_t::z[NLOS]

Altitude [km].

Definition at line 327 of file jurassic.h.

4.3.2.3 double los_t::lon[NLOS]

Longitude [deg].

Definition at line 330 of file jurassic.h.

4.3.2.4 double los_t::lat[NLOS]

Latitude [deg].

Definition at line 333 of file jurassic.h.

4.3.2.5 double los_t::p[NLOS]

Pressure [hPa].

Definition at line 336 of file jurassic.h.

4.3.2.6 double los_t::t[NLOS]

Temperature [K].

Definition at line 339 of file jurassic.h.

4.3.2.7 double los_t::q[NG][NLOS]

Volume mixing ratio.

Definition at line 342 of file jurassic.h.

4.3.2.8 double los_t::k[NW][NLOS]

Extinction [1/km].

Definition at line 345 of file jurassic.h.

4.3.2.9 double los_t::tsurf

Surface temperature [K].

Definition at line 348 of file jurassic.h.

4.3.2.10 double los_t::ds[NLOS]

Segment length [km].

Definition at line 351 of file jurassic.h.

4.3.2.11 double los_t::u[NG][NLOS]

Column density [molecules/cm^2].

Definition at line 354 of file jurassic.h.

The documentation for this struct was generated from the following file:

- jurassic.h

4.4 obs_t Struct Reference

Observation geometry and radiance data.

`#include <jurassic.h>`

Data Fields

- int nr

  Number of ray paths.
- double time [NR]

  Time (seconds since 2000-01-01T00:00Z).
- double obsz [NR]

  Observer altitude [km].
- double obslon [NR]

  Observer longitude [deg].
- double obslat [NR]

  Observer latitude [deg].
- double vpz [NR]

  View point altitude [km].
- double vplon [NR]

  View point longitude [deg].
- double vplat [NR]

  View point latitude [deg].
- double tpz [NR]

  Tangent point altitude [km].
- double tplon [NR]

  Tangent point longitude [deg].
- double tplat [NR]

  Tangent point latitude [deg].
- double tau [ND][NR]

  Transmittance of ray path.
- double rad [ND][NR]

  Radiance [W/(m^2 sr cm^-1)].

4.4.1 Detailed Description

Observation geometry and radiance data.

Definition at line 359 of file jurassic.h.

4.4.2 Field Documentation

4.4.2.1 int obs_t::nr

Number of ray paths.

Definition at line 362 of file jurassic.h.

4.4.2.2 double obs_t::time[NR]

Time (seconds since 2000-01-01T00:00Z).

Definition at line 365 of file jurassic.h.

4.4.2.3 double obs_t::obsz[NR]

Observer altitude [km].

Definition at line 368 of file jurassic.h.

4.4.2.4 double obs_t::obslon[NR]

Observer longitude [deg].

Definition at line 371 of file jurassic.h.

4.4.2.5 double obs_t::obslat[NR]

Observer latitude [deg].

Definition at line 374 of file jurassic.h.

4.4.2.6 double obs_t::vpz[NR]

View point altitude [km].

Definition at line 377 of file jurassic.h.

4.4.2.7 double obs_t::vplon[NR]

View point longitude [deg].

Definition at line 380 of file jurassic.h.

4.4.2.8 double obs_t::vplat[NR]

View point latitude [deg].

Definition at line 383 of file jurassic.h.

4.4.2.9 double obs_t::tpz[NR]

Tangent point altitude [km].

Definition at line 386 of file jurassic.h.

4.4.2.10 double obs_t::tplon[NR]

Tangent point longitude [deg].

Definition at line 389 of file jurassic.h.

4.4.2.11 double obs_t::tplat[NR]

Tangent point latitude [deg].

Definition at line 392 of file jurassic.h.

4.4.2.12 double obs_t::tau[ND][NR]

Transmittance of ray path.

Definition at line 395 of file jurassic.h.

4.4.2.13 double obs_t::rad[ND][NR]

Radiance [W/(m^2 sr cm^-1)].

Definition at line 398 of file jurassic.h.

The documentation for this struct was generated from the following file:

- jurassic.h

4.5 ret_t Struct Reference

Retrieval control parameters.

Data Fields

- char dir [LEN]

  Working directory.
- int kernel_recomp

  Recomputation of kernel matrix (number of iterations).
- int conv_itmax

  Maximum number of iterations.
- double conv_dmin

  Minimum normalized step size in state space.
- int err_ana

  Carry out error analysis (0=no, 1=yes).
- double err_formod [ND]

  Forward model error [%].
- double err_noise [ND]

  Noise error [W/(m^2 sr cm^-1)].
- double err_press

  Pressure error [%].
- double err_press_cz

  Vertical correlation length for pressure error [km].
- double err_press_ch

  Horizontal correlation length for pressure error [km].
- double err_temp

  Temperature error [K].

- double err_temp_cz

  Vertical correlation length for temperature error [km].
- double err_temp_ch

  Horizontal correlation length for temperature error [km].
- double err_q [NG]

  Volume mixing ratio error [%].
- double err_q_cz [NG]

  Vertical correlation length for volume mixing ratio error [km].
- double err_q_ch [NG]

  Horizontal correlation length for volume mixing ratio error [km].
- double err_k [NW]

  Extinction error [1/km].
- double err_k_cz [NW]

  Vertical correlation length for extinction error [km].
- double err_k_ch [NW]

  Horizontal correlation length for extinction error [km].

4.5.1 Detailed Description

Retrieval control parameters.

Definition at line 32 of file retrieval.c.

4.5.2 Field Documentation

4.5.2.1 char ret_t::dir[LEN]

Working directory.

Definition at line 35 of file retrieval.c.

4.5.2.2 int ret_t::kernel_recomp

Recomputation of kernel matrix (number of iterations).

Definition at line 38 of file retrieval.c.

4.5.2.3 int ret_t::conv_itmax

Maximum number of iterations.

Definition at line 41 of file retrieval.c.

4.5.2.4 double ret_t::conv_dmin

Minimum normalized step size in state space.

Definition at line 44 of file retrieval.c.

4.5.2.5 int ret_t::err_ana

Carry out error analysis (0=no, 1=yes).

Definition at line 47 of file retrieval.c.

4.5.2.6 double ret_t::err_formod[ND]

Forward model error [%].

Definition at line 50 of file retrieval.c.

4.5.2.7 double ret_t::err_noise[ND]

Noise error [W/(m^2 sr cm^-1)].

Definition at line 53 of file retrieval.c.

4.5.2.8 double ret_t::err_press

Pressure error [%].

Definition at line 56 of file retrieval.c.

4.5.2.9 double ret_t::err_press_cz

Vertical correlation length for pressure error [km].

Definition at line 59 of file retrieval.c.

4.5.2.10 double ret_t::err_press_ch

Horizontal correlation length for pressure error [km].

Definition at line 62 of file retrieval.c.

4.5.2.11 double ret_t::err_temp

Temperature error [K].

Definition at line 65 of file retrieval.c.

4.5.2.12 double ret_t::err_temp_cz

Vertical correlation length for temperature error [km].

Definition at line 68 of file retrieval.c.

4.5.2.13 double ret_t::err_temp_ch

Horizontal correlation length for temperature error [km].

Definition at line 71 of file retrieval.c.

4.5.2.14 double ret_t::err_q[NG]

Volume mixing ratio error [%].

Definition at line 74 of file retrieval.c.

4.5.2.15 double ret_t::err_q_cz[NG]

Vertical correlation length for volume mixing ratio error [km].

Definition at line 77 of file retrieval.c.

4.5.2.16 double ret_t::err_q_ch[NG]

Horizontal correlation length for volume mixing ratio error [km].

Definition at line 80 of file retrieval.c.

4.5.2.17 double ret_t::err_k[NW]

Extinction error [1/km].

Definition at line 83 of file retrieval.c.

4.5.2.18 double ret_t::err_k_cz[NW]

Vertical correlation length for extinction error [km].

Definition at line 86 of file retrieval.c.

4.5.2.19 double ret_t::err_k_ch[NW]

Horizontal correlation length for extinction error [km].

Definition at line 89 of file retrieval.c.

The documentation for this struct was generated from the following file:

- retrieval.c

4.6 tbl_t Struct Reference

Emissivity look-up tables.

```
#include <jurassic.h>
```

Data Fields

- int np [NG][ND]

  Number of pressure levels.
- int nt [NG][ND][TBLNP]

  Number of temperatures.
- int nu [NG][ND][TBLNP][TBLNT]

  Number of column densities.
- double p [NG][ND][TBLNP]

  Pressure [hPa].
- double t [NG][ND][TBLNP][TBLNT]

  Temperature [K].
- float u [NG][ND][TBLNP][TBLNT][TBLNU]

  Column density [molecules/cm^ 2].
- float eps [NG][ND][TBLNP][TBLNT][TBLNU]

  Emissivity.
- double st [TBLNS]

  Source function temperature [K].
- double sr [ND][TBLNS]

  Source function radiance [W/(m^ 2 sr cm^ -1)].

4.6.1 Detailed Description

Emissivity look-up tables.

Definition at line 403 of file jurassic.h.

4.6.2 Field Documentation

4.6.2.1 int tbl_t::np[NG][ND]

Number of pressure levels.

Definition at line 406 of file jurassic.h.

4.6.2.2 int tbl_t::nt[NG][ND][TBLNP]

Number of temperatures.

Definition at line 409 of file jurassic.h.

4.6.2.3 int tbl_t::nu[NG][ND][TBLNP][TBLNT]

Number of column densities.

Definition at line 412 of file jurassic.h.

4.6.2.4 double tbl_t::p[NG][ND][TBLNP]

Pressure [hPa].

Definition at line 415 of file jurassic.h.

4.6.2.5 double tbl_t::t[NG][ND][TBLNP][TBLNT]

Temperature [K].

Definition at line 418 of file jurassic.h.

4.6.2.6 float tbl_t::u[NG][ND][TBLNP][TBLNT][TBLNU]

Column density [molecules/cm^2].

Definition at line 421 of file jurassic.h.

4.6.2.7 float tbl_t::eps[NG][ND][TBLNP][TBLNT][TBLNU]

Emissivity.

Definition at line 424 of file jurassic.h.

4.6.2.8 double tbl_t::st[TBLNS]

Source function temperature [K].

Definition at line 427 of file jurassic.h.

4.6.2.9 double tbl_t::sr[ND][TBLNS]

Source function radiance [W/(m^2 sr cm^-1)].

Definition at line 430 of file jurassic.h.

The documentation for this struct was generated from the following file:

- jurassic.h

5 File Documentation

5.1 brightness.c File Reference

Convert radiance to brightness temperature.

Functions

- int main (int argc, char ∗argv[ ])

5.1.1 Detailed Description

Convert radiance to brightness temperature.

Definition in file brightness.c.

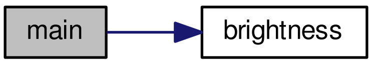
5.1.2 Function Documentation

5.1.2.1 int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 27 of file brightness.c.

```
                {

  double nu, rad;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <rad> <nu>");

  /* Read arguments... */
  rad = atof(argv[1]);
  nu = atof(argv[2]);

  /* Compute brightness temperature... */
  printf("%.10g\n", brightness(rad, nu));

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.2 brightness.c

```
/*
  This file is part of JURASSIC.

  JURASSIC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  JURASSIC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

```

```
int main(
  int argc,
  char *argv[]) {

  double nu, rad;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <rad> <nu>");

  /* Read arguments... */
  rad = atof(argv[1]);
  nu = atof(argv[2]);

  /* Compute brightness temperature... */
  printf("%.10g\n", brightness(rad, nu));

  return EXIT_SUCCESS;
}
```

5.3 climatology.c File Reference

Prepare atmospheric data file from climatological data.

Functions

- int main (int argc, char ∗argv[ ])

5.3.1 Detailed Description

Prepare atmospheric data file from climatological data.

Definition in file climatology.c.

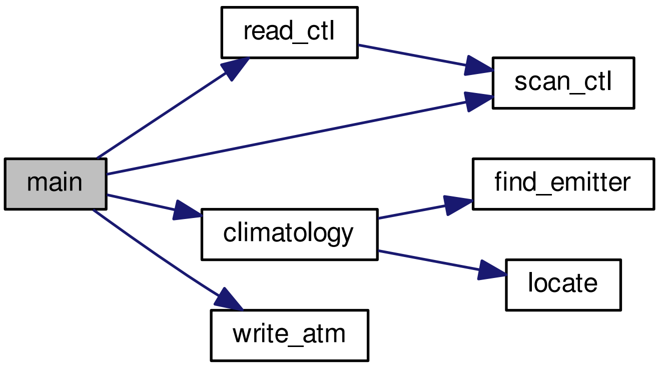
5.3.2 Function Documentation

5.3.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file climatology.c.

```
                {

  static atm_t atm;
  static ctl_t ctl;

  double dz, t0, z, z0, z1;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <atm>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  t0 = scan_ctl(argc, argv, "T0", -1, "0", NULL);
  z0 = scan_ctl(argc, argv, "Z0", -1, "0", NULL);
  z1 = scan_ctl(argc, argv, "Z1", -1, "90", NULL);
  dz = scan_ctl(argc, argv, "DZ", -1, "1", NULL);

  /* Set atmospheric grid... */
  for (z = z0; z <= z1; z += dz) {
    atm.time[atm.np] = t0;
    atm.z[atm.np] = z;
    if ((++atm.np) >= NP)
      ERRMSG("Too many atmospheric grid points!");
  }

  /* Interpolate climatological data... */
  climatology(&ctl, &atm);

  /* Write data to disk... */
  write_atm(NULL, argv[2], &ctl, &atm);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.4 climatology.c

```
/*
  This file is part of JURASSIC.

  JURASSIC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  JURASSIC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static atm_t atm;
  static ctl_t ctl;

  double dz, t0, z, z0, z1;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <atm>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  t0 = scan_ctl(argc, argv, "T0", -1, "0", NULL);
  z0 = scan_ctl(argc, argv, "Z0", -1, "0", NULL);
  z1 = scan_ctl(argc, argv, "Z1", -1, "90", NULL);
  dz = scan_ctl(argc, argv, "DZ", -1, "1", NULL);

  /* Set atmospheric grid... */
  for (z = z0; z <= z1; z += dz) {
    atm.time[atm.np] = t0;
    atm.z[atm.np] = z;
    if ((++atm.np) >= NP)
      ERRMSG("Too many atmospheric grid points!");
  }

  /* Interpolate climatological data... */
  climatology(&ctl, &atm);

  /* Write data to disk... */
  write_atm(NULL, argv[2], &ctl, &atm);

  return EXIT_SUCCESS;
}
```

5.5 formod.c File Reference

JURASSIC forward model.

Functions

- void call_formod (ctl_t ∗ctl, const char ∗wrkdir, const char ∗obsfile, const char ∗atmfile, const char ∗radfile, const char ∗task)

  Perform forward model calculations in a single directory.
- int main (int argc, char ∗argv[ ])

5.5.1 Detailed Description

JURASSIC forward model.

Definition in file formod.c.

5.5.2 Function Documentation

5.5.2.1 void call_formod (ctl_t ∗ *ctl,* const char ∗ *wrkdir,* const char ∗ *obsfile,* const char ∗ *atmfile,* const char ∗ *radfile,* const char ∗ *task*)

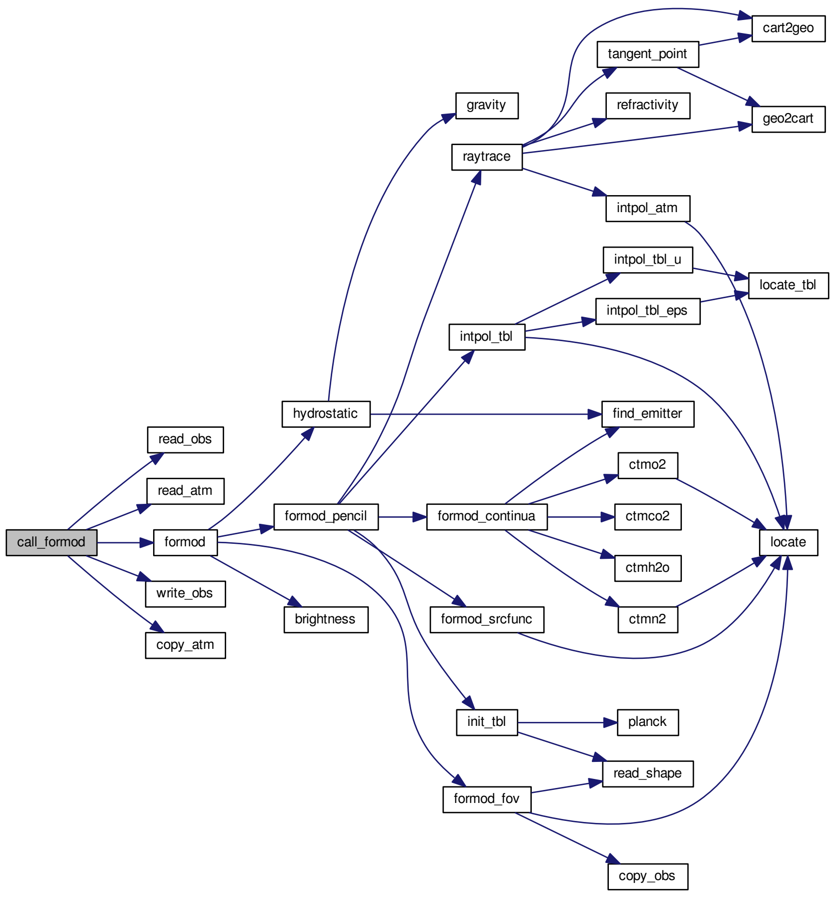
Perform forward model calculations in a single directory.

Definition at line 97 of file formod.c.

```
                     {

  static atm_t atm, atm2;
  static obs_t obs, obs2;

  char filename[LEN];

  int id, ig, ig2, ip, ir, iw;

  /* Read observation geometry... */
  read_obs(wrkdir, obsfile, ctl, &obs);

  /* Read atmospheric data... */
  read_atm(wrkdir, atmfile, ctl, &atm);

  /* Compute multiple profiles... */
  if (task[0] == 'p' || task[0] == 'P') {

    /* Loop over ray paths... */
    for (ir = 0; ir < obs.nr; ir++) {

      /* Get atmospheric data... */
      atm2.np = 0;
      for (ip = 0; ip < atm.np; ip++)
        if (atm.time[ip] == obs.time[ir]) {
          atm2.time[atm2.np] = atm.time[ip];
          atm2.z[atm2.np] = atm.z[ip];
          atm2.lon[atm2.np] = atm.lon[ip];
          atm2.lat[atm2.np] = atm.lat[ip];
          atm2.p[atm2.np] = atm.p[ip];
          atm2.t[atm2.np] = atm.t[ip];
          for (ig = 0; ig < ctl->ng; ig++)
            atm2.q[ig][atm2.np] = atm.q[ig][ip];
          for (iw = 0; iw < ctl->nw; iw++)
            atm2.k[iw][atm2.np] = atm.k[iw][ip];
          atm2.np++;
        }

      /* Get observation data... */
      obs2.nr = 1;
      obs2.time[0] = obs.time[ir];
      obs2.vpz[0] = obs.vpz[ir];
      obs2.vplon[0] = obs.vplon[ir];
      obs2.vplat[0] = obs.vplat[ir];
      obs2.obsz[0] = obs.obsz[ir];
      obs2.obslon[0] = obs.obslon[ir];
      obs2.obslat[0] = obs.obslat[ir];

      /* Check number of data points... */
      if (atm2.np > 0) {

        /* Call forward model... */
        formod(ctl, &atm2, &obs2);

        /* Save radiance data... */
        for (id = 0; id < ctl->nd; id++) {
          obs.rad[id][ir] = obs2.rad[id][0];
          obs.tau[id][ir] = obs2.tau[id][0];
        }
      }
    }

    /* Write radiance data... */
    write_obs(wrkdir, radfile, ctl, &obs);
  }

  /* Compute single profile... */
  else {

    /* Call forward model... */
    formod(ctl, &atm, &obs);

    /* Save radiance data... */
    write_obs(wrkdir, radfile, ctl, &obs);

    /* Compute contributions... */
    if (task[0] == 'c' || task[0] == 'C') {

      /* Switch off continua... */
      ctl->ctm_co2 = 0;
      ctl->ctm_h2o = 0;
      ctl->ctm_n2 = 0;
      ctl->ctm_o2 = 0;

      /* Loop over emitters... */
      for (ig = 0; ig < ctl->ng; ig++) {

        /* Copy atmospheric data... */
        copy_atm(ctl, &atm2, &atm, 0);

        /* Set extinction to zero... */
        for (iw = 0; iw < ctl->nw; iw++)
          for (ip = 0; ip < atm2.np; ip++)
            atm2.k[iw][ip] = 0;

        /* Set volume mixing ratios to zero... */
        for (ig2 = 0; ig2 < ctl->ng; ig2++)
          if (ig2 != ig)
            for (ip = 0; ip < atm2.np; ip++)
              atm2.q[ig2][ip] = 0;

        /* Call forward model... */
```

```
          formod(ctl, &atm2, &obs);

          /* Save radiance data... */
          sprintf(filename, "%s.%s", radfile, ctl->emitter[ig]);
          write_obs(wrkdir, filename, ctl, &obs);
        }

        /* Copy atmospheric data... */
        copy_atm(ctl, &atm2, &atm, 0);

        /* Set volume mixing ratios to zero... */
        for (ig = 0; ig < ctl->ng; ig++)
          for (ip = 0; ip < atm2.np; ip++)
            atm2.q[ig][ip] = 0;

        /* Call forward model... */
        formod(ctl, &atm2, &obs);

        /* Save radiance data... */
        sprintf(filename, "%s.EXTINCT", radfile);
        write_obs(wrkdir, filename, ctl, &obs);
      }

      /* Measure CPU-time... */
      if (task[0] == 't' || task[0] == 'T') {
        TIMER("formod", 1);
        formod(ctl, &atm, &obs);
        TIMER("formod", 3);
      }
    }
}
```

Here is the call graph for this function:

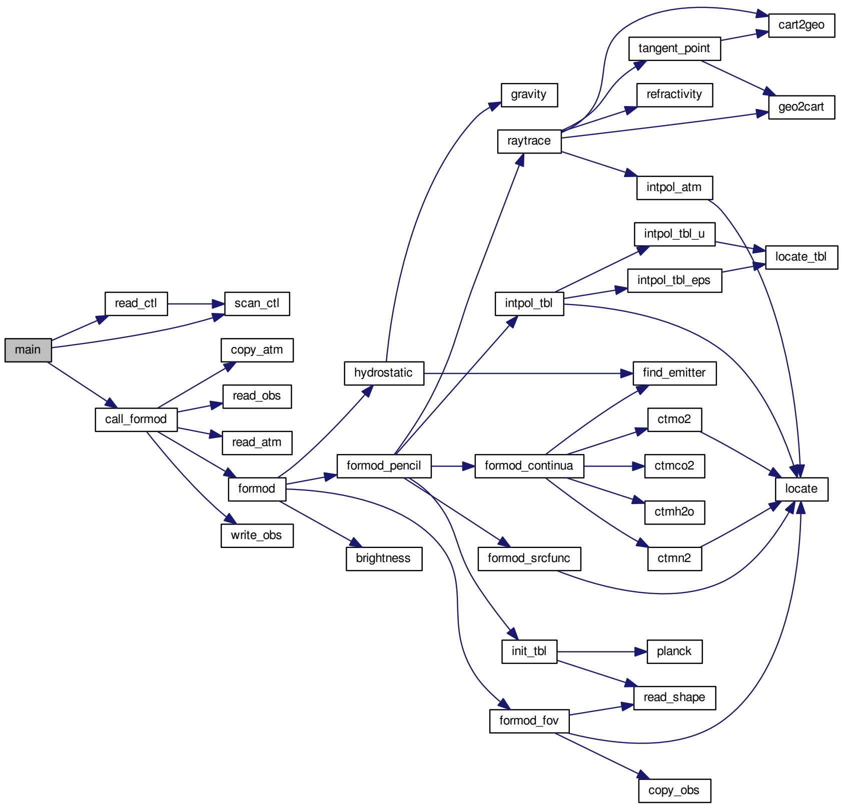


5.5.2.2 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 44 of file formod.c.

```
                  {

  static ctl_t ctl;

  FILE *in;

  char dirlist[LEN], task[LEN], wrkdir[LEN];

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <obs> <atm> <rad>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Get task... */
  scan_ctl(argc, argv, "TASK", -1, "-", task);

  /* Get dirlist... */
  scan_ctl(argc, argv, "DIRLIST", -1, "-", dirlist);

  /* Single forward calculation... */
  if (dirlist[0] == '-')
    call_formod(&ctl, NULL, argv[2], argv[3], argv[4], task);

  /* Work on directory list... */
  else {

    /* Open directory list... */
    if (!(in = fopen(dirlist, "r")))
      ERRMSG("Cannot open directory list!");

    /* Loop over directories... */
    while (fscanf(in, "%s", wrkdir) != EOF) {

      /* Write info... */
      printf("\nWorking directory: %s\n", wrkdir);

      /* Call forward model... */
      call_formod(&ctl, wrkdir, argv[2], argv[3], argv[4], task);
    }

    /* Close dirlist... */
    fclose(in);
  }

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.6 formod.c

```
/*
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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
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  JURASSIC is distributed in the hope that it will be useful,
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  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void call_formod(
  ctl_t * ctl,
  const char *wrkdir,
  const char *obsfile,
  const char *atmfile,
  const char *radfile,
  const char *task);

/* ------------------------------------------------------------
```

```
  Main...
  ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  static ctl_t ctl;

  FILE *in;

  char dirlist[LEN], task[LEN], wrkdir[LEN];

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <obs> <atm> <rad>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Get task... */
  scan_ctl(argc, argv, "TASK", -1, "-", task);

  /* Get dirlist... */
  scan_ctl(argc, argv, "DIRLIST", -1, "-", dirlist);

  /* Single forward calculation... */
  if (dirlist[0] == '-')
    call_formod(&ctl, NULL, argv[2], argv[3], argv[4], task);

  /* Work on directory list... */
  else {

    /* Open directory list... */
    if (!(in = fopen(dirlist, "r")))
      ERRMSG("Cannot open directory list!");

    /* Loop over directories... */
    while (fscanf(in, "%s", wrkdir) != EOF) {

      /* Write info... */
      printf("\nWorking directory: %s\n", wrkdir);

      /* Call forward model... */
      call_formod(&ctl, wrkdir, argv[2], argv[3], argv[4], task);
    }

    /* Close dirlist... */
    fclose(in);
  }

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void call_formod(
  ctl_t * ctl,
  const char *wrkdir,
  const char *obsfile,
  const char *atmfile,
  const char *radfile,
  const char *task) {

  static atm_t atm, atm2;
  static obs_t obs, obs2;

  char filename[LEN];

  int id, ig, ig2, ip, ir, iw;

  /* Read observation geometry... */
  read_obs(wrkdir, obsfile, ctl, &obs);

  /* Read atmospheric data... */
  read_atm(wrkdir, atmfile, ctl, &atm);

  /* Compute multiple profiles... */
  if (task[0] == 'p' || task[0] == 'P') {

    /* Loop over ray paths... */
    for (ir = 0; ir < obs.nr; ir++) {

      /* Get atmospheric data... */
      atm2.np = 0;
      for (ip = 0; ip < atm.np; ip++)
        if (atm.time[ip] == obs.time[ir]) {
          atm2.time[atm2.np] = atm.time[ip];
          atm2.z[atm2.np] = atm.z[ip];
          atm2.lon[atm2.np] = atm.lon[ip];
          atm2.lat[atm2.np] = atm.lat[ip];
          atm2.p[atm2.np] = atm.p[ip];
          atm2.t[atm2.np] = atm.t[ip];
          for (ig = 0; ig < ctl->ng; ig++)
            atm2.q[ig][atm2.np] = atm.q[ig][ip];
          for (iw = 0; iw < ctl->nw; iw++)
            atm2.k[iw][atm2.np] = atm.k[iw][ip];
          atm2.np++;
        }

      /* Get observation data... */
      obs2.nr = 1;
      obs2.time[0] = obs.time[ir];
      obs2.vpz[0] = obs.vpz[ir];
      obs2.vplon[0] = obs.vplon[ir];
      obs2.vplat[0] = obs.vplat[ir];
      obs2.obsz[0] = obs.obsz[ir];
      obs2.obslon[0] = obs.obslon[ir];
      obs2.obslat[0] = obs.obslat[ir];

      /* Check number of data points... */
      if (atm2.np > 0) {

        /* Call forward model... */
        formod(ctl, &atm2, &obs2);

        /* Save radiance data... */
        for (id = 0; id < ctl->nd; id++) {
          obs.rad[id][ir] = obs2.rad[id][0];
          obs.tau[id][ir] = obs2.tau[id][0];
        }
      }
    }

    /* Write radiance data... */
    write_obs(wrkdir, radfile, ctl, &obs);
  }

  /* Compute single profile... */
  else {

    /* Call forward model... */
    formod(ctl, &atm, &obs);

    /* Save radiance data... */
    write_obs(wrkdir, radfile, ctl, &obs);

    /* Compute contributions... */
    if (task[0] == 'c' || task[0] == 'C') {

      /* Switch off continua... */
      ctl->ctm_co2 = 0;
      ctl->ctm_h2o = 0;
      ctl->ctm_n2 = 0;
      ctl->ctm_o2 = 0;

      /* Loop over emitters... */
      for (ig = 0; ig < ctl->ng; ig++) {

        /* Copy atmospheric data... */
        copy_atm(ctl, &atm2, &atm, 0);

        /* Set extinction to zero... */
        for (iw = 0; iw < ctl->nw; iw++)
          for (ip = 0; ip < atm2.np; ip++)
            atm2.k[iw][ip] = 0;

        /* Set volume mixing ratios to zero... */
        for (ig2 = 0; ig2 < ctl->ng; ig2++)
          if (ig2 != ig)
            for (ip = 0; ip < atm2.np; ip++)
              atm2.q[ig2][ip] = 0;

        /* Call forward model... */
        formod(ctl, &atm2, &obs);

        /* Save radiance data... */
        sprintf(filename, "%s.%s", radfile, ctl->emitter[ig]);
        write_obs(wrkdir, filename, ctl, &obs);
      }

      /* Copy atmospheric data... */
      copy_atm(ctl, &atm2, &atm, 0);

      /* Set volume mixing ratios to zero... */
      for (ig = 0; ig < ctl->ng; ig++)
        for (ip = 0; ip < atm2.np; ip++)
          atm2.q[ig][ip] = 0;

      /* Call forward model... */
      formod(ctl, &atm2, &obs);

      /* Save radiance data... */
      sprintf(filename, "%s.EXTINCT", radfile);
      write_obs(wrkdir, filename, ctl, &obs);
    }

    /* Measure CPU-time... */
    if (task[0] == 't' || task[0] == 'T') {
      TIMER("formod", 1);
      formod(ctl, &atm, &obs);
      TIMER("formod", 3);
    }
  }
}
```

5.7 hydrostatic.c File Reference

Recalculate pressure based on hydrostatic equilibrium.

Functions

- int main (int argc, char ∗argv[ ])

5.7.1 Detailed Description

Recalculate pressure based on hydrostatic equilibrium.

Definition in file hydrostatic.c.

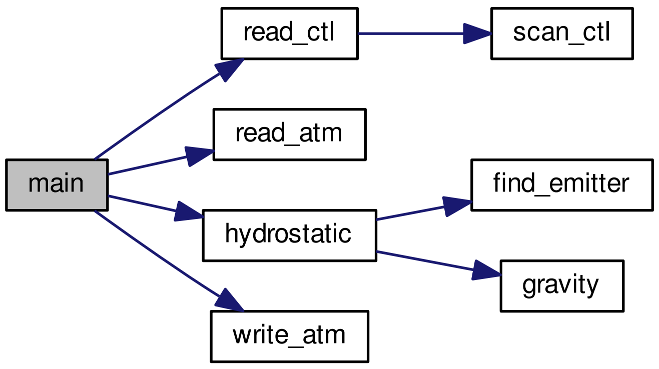
5.7.2 Function Documentation

5.7.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file hydrostatic.c.

```
                {

  static atm_t atm;
  static ctl_t ctl;

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_hyd>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Check reference height... */
  if (ctl.hydz < 0)
    ERRMSG("Set HYDZ>=0!");

  /* Read atmospheric data... */
  read_atm(NULL, argv[2], &ctl, &atm);

  /* Build atmosphere based on hydrostatic equilibrium... */
  hydrostatic(&ctl, &atm);

  /* Write atmospheric data... */
  write_atm(NULL, argv[3], &ctl, &atm);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.8 hydrostatic.c

```
/*
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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
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  JURASSIC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copyright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static atm_t atm;
  static ctl_t ctl;

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_hyd>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Check reference height... */
  if (ctl.hydz < 0)
    ERRMSG("Set HYDZ>=0!");

  /* Read atmospheric data... */
  read_atm(NULL, argv[2], &ctl, &atm);

  /* Build atmosphere based on hydrostatic equilibrium... */
  hydrostatic(&ctl, &atm);

  /* Write atmospheric data... */
  write_atm(NULL, argv[3], &ctl, &atm);

  return EXIT_SUCCESS;
}
```

5.9 interpolate.c File Reference

Interpolate atmospheric data to another spatial grid.

Functions

- int main (int argc, char ∗argv[ ])

5.9.1 Detailed Description

Interpolate atmospheric data to another spatial grid.

Definition in file interpolate.c.

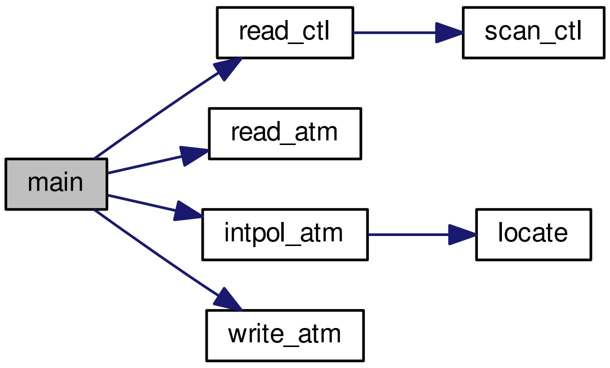
5.9.2 Function Documentation

5.9.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file interpolate.c.

```
                 {

  static atm_t atm_in, atm_pts;
  static ctl_t ctl;

  double k[NW], q[NG];

  int ig, ip, iw;

  /* Interpolate atmospheric data... */

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_pts> <atm_out>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Read atmospheric data... */
  read_atm(NULL, argv[2], &ctl, &atm_in);
  read_atm(NULL, argv[3], &ctl, &atm_pts);

  /* Interpolate atmospheric data... */
  for (ip = 0; ip < atm_pts.np; ip++) {
    intpol_atm(&ctl, &atm_in, atm_pts.z[ip],
               &atm_pts.p[ip], &atm_pts.t[ip], q, k);
    for (ig = 0; ig < ctl.ng; ig++)
      atm_pts.q[ig][ip] = q[ig];
    for (iw = 0; iw < ctl.nw; iw++)
      atm_pts.k[iw][ip] = k[iw];
  }

  /* Save interpolated data... */
  write_atm(NULL, argv[4], &ctl, &atm_pts);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.10 interpolate.c

```
/*
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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static atm_t atm_in, atm_pts;
  static ctl_t ctl;

  double k[NW], q[NG];

  int ig, ip, iw;

  /* Interpolate atmospheric data... */

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <atm_in> <atm_pts> <atm_out>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Read atmospheric data... */
  read_atm(NULL, argv[2], &ctl, &atm_in);
  read_atm(NULL, argv[3], &ctl, &atm_pts);

  /* Interpolate atmospheric data... */
  for (ip = 0; ip < atm_pts.np; ip++) {
    intpol_atm(&ctl, &atm_in, atm_pts.z[ip],
               &atm_pts.p[ip], &atm_pts.t[ip], q, k);
    for (ig = 0; ig < ctl.ng; ig++)
      atm_pts.q[ig][ip] = q[ig];
    for (iw = 0; iw < ctl.nw; iw++)
      atm_pts.k[iw][ip] = k[iw];
  }

  /* Save interpolated data... */
  write_atm(NULL, argv[4], &ctl, &atm_pts);

  return EXIT_SUCCESS;
}
```

5.11 jsec2time.c File Reference

Convert Julian seconds to date.

Functions

- int main (int argc, char ∗argv[ ])

5.11.1 Detailed Description

Convert Julian seconds to date.

Definition in file jsec2time.c.

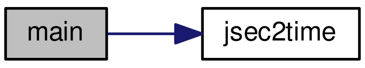
5.11.2 Function Documentation

5.11.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file jsec2time.c.

```
                  {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 2)
    ERRMSG("Give parameters: <jsec>");

  /* Read arguments... */
  jsec = atof(argv[1]);

  /* Convert time... */
  jsec2time(jsec, &year, &mon, &day, &hour, &min, &sec, &remain);
  printf("%d %d %d %d %d %d %g\n", year, mon, day, hour, min, sec, remain);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.12 jsec2time.c

```
/*
  This file is part of JURASSIC.

  JURASSIC is free software: you can redistribute it and/or modify
  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

  JURASSIC is distributed in the hope that it will be useful,
  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 2)
    ERRMSG("Give parameters: <jsec>");

  /* Read arguments... */
  jsec = atof(argv[1]);

  /* Convert time... */
  jsec2time(jsec, &year, &mon, &day, &hour, &min, &sec, &remain);
  printf("%d %d %d %d %d %d %g\n", year, mon, day, hour, min, sec, remain);

  return EXIT_SUCCESS;
}
```

5.13 jurassic.c File Reference

JURASSIC library definitions.

Functions

- size_t atm2x (ctl_t *ctl, atm_t *atm, gsl_vector *x, int *iqa, int *ipa)

  Compose state vector or parameter vector.
- void atm2x_help (atm_t *atm, double zmin, double zmax, double *value, int val_iqa, gsl_vector *x, int *iqa, int *ipa, size_t *n)

  Add elements to state vector.
- double brightness (double rad, double nu)

  Compute brightness temperature.
- void cart2geo (double *x, double *z, double *lon, double *lat)

  Convert Cartesian coordinates to geolocation.
- void climatology (ctl_t *ctl, atm_t *atm)

  Interpolate climatological data.
- double ctmco2 (double nu, double p, double t, double u)

  Compute carbon dioxide continuum (optical depth).
- double ctmh2o (double nu, double p, double t, double q, double u)

  Compute water vapor continuum (optical depth).

- double ctmn2 (double nu, double p, double t)

  Compute nitrogen continuum (absorption coefficient).
- double ctmo2 (double nu, double p, double t)

  Compute oxygen continuum (absorption coefficient).
- void copy_atm (ctl_t ∗ctl, atm_t ∗atm_dest, atm_t ∗atm_src, int init)

  Copy and initialize atmospheric data.
- void copy_obs (ctl_t ∗ctl, obs_t ∗obs_dest, obs_t ∗obs_src, int init)

  Copy and initialize observation data.
- int find_emitter (ctl_t ∗ctl, const char ∗emitter)

  Find index of an emitter.
- void formod (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs)

  Determine ray paths and compute radiative transfer.
- void formod_continua (ctl_t ∗ctl, los_t ∗los, int ip, double ∗beta)

  Compute absorption coefficient of continua.
- void formod_fov (ctl_t ∗ctl, obs_t ∗obs)

  Apply field of view convolution.
- void formod_pencil (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, int ir)

  Compute radiative transfer for a pencil beam.
- void formod_srcfunc (ctl_t ∗ctl, tbl_t ∗tbl, double t, double ∗src)

  Compute Planck source function.
- void geo2cart (double z, double lon, double lat, double ∗x)

  Convert geolocation to Cartesian coordinates.
- double gravity (double z, double lat)

  Determine gravity of Earth.
- void hydrostatic (ctl_t ∗ctl, atm_t ∗atm)

  Set hydrostatic equilibrium.
- void idx2name (ctl_t ∗ctl, int idx, char ∗quantity)

  Determine name of state vector quantity for given index.
- void init_tbl (ctl_t ∗ctl, tbl_t ∗tbl)

  Initialize look-up tables.
- void intpol_atm (ctl_t ∗ctl, atm_t ∗atm, double z, double ∗p, double ∗t, double ∗q, double ∗k)

  Interpolate atmospheric data.
- void intpol_tbl (ctl_t ∗ctl, tbl_t ∗tbl, los_t ∗los, int ip, double tau_path[NG][ND], double tau_seg[ND])

  Get transmittance from look-up tables.
- double intpol_tbl_eps (tbl_t ∗tbl, int ig, int id, int ip, int it, double u)

  Interpolate emissivity from look-up tables.
- double intpol_tbl_u (tbl_t ∗tbl, int ig, int id, int ip, int it, double eps)

  Interpolate column density from look-up tables.
- void jsec2time (double jsec, int ∗year, int ∗mon, int ∗day, int ∗hour, int ∗min, int ∗sec, double ∗remain)

  Convert seconds to date.
- void kernel (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, gsl_matrix ∗k)

  Compute Jacobians.
- int locate (double ∗xx, int n, double x)

  Find array index.
- int locate_tbl (float ∗xx, int n, double x)

  Find array index in float array.
- size_t obs2y (ctl_t ∗ctl, obs_t ∗obs, gsl_vector ∗y, int ∗ida, int ∗ira)

  Compose measurement vector.
- double planck (double t, double nu)

  Compute Planck function.
- void raytrace (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, los_t ∗los, int ir)

Do ray-tracing to determine LOS.
- void read_atm (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

  Read atmospheric data.
- void read_ctl (int argc, char ∗argv[ ], ctl_t ∗ctl)

  Read forward model control parameters.
- void read_matrix (const char ∗dirname, const char ∗filename, gsl_matrix ∗matrix)

  Read matrix.
- void read_obs (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, obs_t ∗obs)

  Read observation data.
- void read_shape (const char ∗filename, double ∗x, double ∗y, int ∗n)

  Read shape function.
- double refractivity (double p, double t)

  Compute refractivity (return value is n - 1).
- double scan_ctl (int argc, char ∗argv[ ], const char ∗varname, int arridx, const char ∗defvalue, char ∗value)

  Search control parameter file for variable entry.
- void tangent_point (los_t ∗los, double ∗tpz, double ∗tplon, double ∗tplat)

  Find tangent point of a given LOS.
- void time2jsec (int year, int mon, int day, int hour, int min, int sec, double remain, double ∗jsec)

  Convert date to seconds.
- void timer (const char ∗name, const char ∗file, const char ∗func, int line, int mode)

  Measure wall-clock time.
- void write_atm (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

  Write atmospheric data.
- void write_matrix (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, gsl_matrix ∗matrix, atm_t ∗atm, obs_t ∗obs, const char ∗rowspace, const char ∗colspace, const char ∗sort)

  Write matrix.
- void write_obs (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, obs_t ∗obs)

  Write observation data.
- void x2atm (ctl_t ∗ctl, gsl_vector ∗x, atm_t ∗atm)

  Decompose parameter vector or state vector.
- void x2atm_help (atm_t ∗atm, double zmin, double zmax, double ∗value, gsl_vector ∗x, size_t ∗n)

  Extract elements from state vector.
- void y2obs (ctl_t ∗ctl, gsl_vector ∗y, obs_t ∗obs)

  Decompose measurement vector.

5.13.1 Detailed Description

JURASSIC library definitions.

Definition in file jurassic.c.

5.13.2 Function Documentation

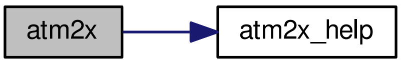
5.13.2.1 size_t atm2x (ctl_t ∗ *ctl,* atm_t ∗ *atm,* gsl_vector ∗ *x,* int ∗ *iqa,* int ∗ *ipa*)

Compose state vector or parameter vector.

Definition at line 29 of file jurassic.c.

```
          {

  int ig, iw;

  size_t n = 0;

  /* Add pressure... */
  atm2x_help(atm, ctl->retp_zmin, ctl->retp_zmax,
             atm->p, IDXP, x, iqa, ipa, &n);

  /* Add temperature... */
  atm2x_help(atm, ctl->rett_zmin, ctl->rett_zmax,
             atm->t, IDXT, x, iqa, ipa, &n);

  /* Add volume mixing ratios... */
  for (ig = 0; ig < ctl->ng; ig++)
    atm2x_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], IDXQ(ig), x, iqa, ipa, &n);

  /* Add extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    atm2x_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], IDXK(iw), x, iqa, ipa, &n);

  return n;
}
```

Here is the call graph for this function:



5.13.2.2 void atm2x_help (atm_t * *atm*, double *zmin*, double *zmax*, double * *value*, int *val_iqa*, gsl_vector * *x*, int * *iqa*, int * *ipa*, size_t * *n*)

Add elements to state vector.

Definition at line 63 of file jurassic.c.

```
            {

  int ip;

  /* Add elements to state vector... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      if (x != NULL)
        gsl_vector_set(x, *n, value[ip]);
      if (iqa != NULL)
        iqa[*n] = val_iqa;
      if (ipa != NULL)
        ipa[*n] = ip;
      (*n)++;
    }
}
```

5.13.2.3 double brightness (double *rad*, double *nu*)

Compute brightness temperature.

Definition at line 91 of file jurassic.c.

```
           {

  return C2 * nu / gsl_log1p(C1 * gsl_pow_3(nu) / rad);
}
```

5.13.2.4 void cart2geo (double ∗ *x*, double ∗ *z*, double ∗ *lon*, double ∗ *lat*)

Convert Cartesian coordinates to geolocation.

Definition at line 101 of file jurassic.c.

```
               {

  double radius;

  radius = NORM(x);
  *lat = asin(x[2] / radius) * 180 / M_PI;
  *lon = atan2(x[1], x[0]) * 180 / M_PI;
  *z = radius - RE;
}
```

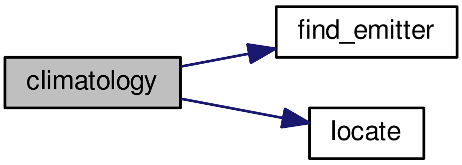
5.13.2.5 void climatology (ctl_t ∗ *ctl*, atm_t ∗ *atm_mean*)

Interpolate climatological data.

Definition at line 117 of file jurassic.c.

```
               {

  static double z[121] = {
    0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
    20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37,
    38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
    56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73,
    74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91,
    92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107,
    108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120
  };

  static double pre[121] = {
    1017, 901.083, 796.45, 702.227, 617.614, 541.644, 473.437, 412.288,
    357.603, 308.96, 265.994, 228.348, 195.619, 167.351, 143.039, 122.198,
    104.369, 89.141, 76.1528, 65.0804, 55.641, 47.591, 40.7233, 34.8637,
    29.8633, 25.5956, 21.9534, 18.8445, 16.1909, 13.9258, 11.9913,
    10.34, 8.92988, 7.72454, 6.6924, 5.80701, 5.04654, 4.39238, 3.82902,
    3.34337, 2.92413, 2.56128, 2.2464, 1.97258, 1.73384, 1.52519, 1.34242,
    1.18197, 1.04086, 0.916546, 0.806832, 0.709875, 0.624101, 0.548176,
    0.480974, 0.421507, 0.368904, 0.322408, 0.281386, 0.245249, 0.213465,
    0.185549, 0.161072, 0.139644, 0.120913, 0.104568, 0.0903249, 0.0779269,
    0.0671493, 0.0577962, 0.0496902, 0.0426736, 0.0366093, 0.0313743,
    0.0268598, 0.0229699, 0.0196206, 0.0167399, 0.0142646, 0.0121397,
    0.0103181, 0.00875775, 0.00742226, 0.00628076, 0.00530519, 0.00447183,
    0.00376124, 0.00315632, 0.00264248, 0.00220738, 0.00184003, 0.00153095,
    0.00127204, 0.00105608, 0.000876652, 0.00072798, 0.00060492,
    0.000503201, 0.000419226, 0.000349896, 0.000292659, 0.000245421,
    0.000206394, 0.000174125, 0.000147441, 0.000125333, 0.000106985,
    9.173e-05, 7.90172e-05, 6.84172e-05, 5.95574e-05, 5.21183e-05,
    4.58348e-05, 4.05127e-05, 3.59987e-05, 3.21583e-05, 2.88718e-05,
    2.60322e-05, 2.35687e-05, 2.14263e-05, 1.95489e-05
  };

  static double tem[121] = {
    285.14, 279.34, 273.91, 268.3, 263.24, 256.55, 250.2, 242.82, 236.17,
    229.87, 225.04, 221.19, 218.85, 217.19, 216.2, 215.68, 215.42, 215.55,
    215.92, 216.4, 216.93, 217.45, 218, 218.68, 219.39, 220.25, 221.3,
    222.41, 223.88, 225.42, 227.2, 229.52, 231.89, 234.51, 236.85, 239.42,
    241.94, 244.57, 247.36, 250.32, 253.34, 255.82, 258.27, 260.39,
    262.03, 263.45, 264.2, 264.78, 264.67, 264.38, 263.24, 262.03, 260.02,
    258.09, 255.63, 253.28, 250.43, 247.81, 245.26, 242.77, 240.38,
    237.94, 235.79, 233.53, 231.5, 229.53, 227.6, 225.62, 223.77, 222.06,
    220.33, 218.69, 217.18, 215.64, 214.13, 212.52, 210.86, 209.25,
    207.49, 205.81, 204.11, 202.22, 200.32, 198.39, 195.92, 193.46,
    190.94, 188.31, 185.82, 183.57, 181.43, 179.74, 178.64, 178.1, 178.25,
    178.7, 179.41, 180.67, 182.31, 184.18, 186.6, 189.53, 192.66, 196.54,
    201.13, 205.93, 211.73, 217.86, 225, 233.53, 242.57, 252.14, 261.48,
    272.97, 285.26, 299.12, 312.2, 324.17, 338.34, 352.56, 365.28
  };

  static double c2h2[121] = {
    1.352e-09, 2.83e-10, 1.269e-10, 6.926e-11, 4.346e-11, 2.909e-11,
    2.014e-11, 1.363e-11, 8.71e-12, 5.237e-12, 2.718e-12, 1.375e-12,
  5.786e-13, 2.16e-13, 7.317e-14, 2.551e-14, 1.055e-14, 4.758e-15,
  2.056e-15, 7.703e-16, 2.82e-16, 1.035e-16, 4.382e-17, 1.946e-17,
  9.638e-18, 5.2e-18, 2.811e-18, 1.494e-18, 7.925e-19, 4.213e-19,
  1.998e-19, 8.78e-20, 3.877e-20, 1.728e-20, 7.743e-21, 3.536e-21,
  1.623e-21, 7.508e-22, 3.508e-22, 1.65e-22, 7.837e-23, 3.733e-23,
  1.808e-23, 8.77e-24, 4.285e-24, 2.095e-24, 1.032e-24, 5.082e-25,
  2.506e-25, 1.236e-25, 6.088e-26, 2.996e-26, 1.465e-26, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double c2h6[121] = {
  2.667e-09, 2.02e-09, 1.658e-09, 1.404e-09, 1.234e-09, 1.109e-09,
  1.012e-09, 9.262e-10, 8.472e-10, 7.71e-10, 6.932e-10, 6.216e-10,
  5.503e-10, 4.87e-10, 4.342e-10, 3.861e-10, 3.347e-10, 2.772e-10,
  2.209e-10, 1.672e-10, 1.197e-10, 8.536e-11, 5.783e-11, 3.846e-11,
  2.495e-11, 1.592e-11, 1.017e-11, 6.327e-12, 3.895e-12, 2.403e-12,
  1.416e-12, 8.101e-13, 4.649e-13, 2.686e-13, 1.557e-13, 9.14e-14,
  5.386e-14, 3.19e-14, 1.903e-14, 1.14e-14, 6.875e-15, 4.154e-15,
  2.538e-15, 1.553e-15, 9.548e-16, 5.872e-16, 3.63e-16, 2.244e-16,
  1.388e-16, 8.587e-17, 5.308e-17, 3.279e-17, 2.017e-17, 1.238e-17,
  7.542e-18, 4.585e-18, 2.776e-18, 1.671e-18, 9.985e-19, 5.937e-19,
  3.518e-19, 2.07e-19, 1.215e-19, 7.06e-20, 4.097e-20, 2.37e-20,
  1.363e-20, 7.802e-21, 4.441e-21, 2.523e-21, 1.424e-21, 8.015e-22,
  4.497e-22, 2.505e-22, 1.391e-22, 7.691e-23, 4.238e-23, 2.331e-23,
  1.274e-23, 6.929e-24, 3.752e-24, 2.02e-24, 1.083e-24, 5.774e-25,
  3.041e-25, 1.593e-25, 8.308e-26, 4.299e-26, 2.195e-26, 1.112e-26,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double ccl4[121] = {
  1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10,
  1.075e-10, 1.075e-10, 1.075e-10, 1.06e-10, 1.024e-10, 9.69e-11,
  8.93e-11, 8.078e-11, 7.213e-11, 6.307e-11, 5.383e-11, 4.49e-11,
  3.609e-11, 2.705e-11, 1.935e-11, 1.385e-11, 8.35e-12, 5.485e-12,
  3.853e-12, 2.22e-12, 5.875e-13, 3.445e-13, 1.015e-13, 6.075e-14,
  4.383e-14, 2.692e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14
};

static double ch4[121] = {
  1.864e-06, 1.835e-06, 1.819e-06, 1.805e-06, 1.796e-06, 1.788e-06,
  1.782e-06, 1.776e-06, 1.769e-06, 1.761e-06, 1.749e-06, 1.734e-06,
  1.716e-06, 1.692e-06, 1.654e-06, 1.61e-06, 1.567e-06, 1.502e-06,
  1.433e-06, 1.371e-06, 1.323e-06, 1.277e-06, 1.232e-06, 1.188e-06,
  1.147e-06, 1.108e-06, 1.07e-06, 1.027e-06, 9.854e-07, 9.416e-07,
  8.933e-07, 8.478e-07, 7.988e-07, 7.515e-07, 7.07e-07, 6.64e-07,
  6.239e-07, 5.864e-07, 5.512e-07, 5.184e-07, 4.87e-07, 4.571e-07,
  4.296e-07, 4.04e-07, 3.802e-07, 3.578e-07, 3.383e-07, 3.203e-07,
  3.032e-07, 2.889e-07, 2.76e-07, 2.635e-07, 2.519e-07, 2.409e-07,
  2.302e-07, 2.219e-07, 2.144e-07, 2.071e-07, 1.999e-07, 1.93e-07,
  1.862e-07, 1.795e-07, 1.731e-07, 1.668e-07, 1.607e-07, 1.548e-07,
  1.49e-07, 1.434e-07, 1.38e-07, 1.328e-07, 1.277e-07, 1.227e-07,
  1.18e-07, 1.134e-07, 1.089e-07, 1.046e-07, 1.004e-07, 9.635e-08,
  9.245e-08, 8.867e-08, 8.502e-08, 8.15e-08, 7.809e-08, 7.48e-08,
  7.159e-08, 6.849e-08, 6.55e-08, 6.262e-08, 5.98e-08, 5.708e-08,
  5.448e-08, 5.194e-08, 4.951e-08, 4.72e-08, 4.5e-08, 4.291e-08,
  4.093e-08, 3.905e-08, 3.729e-08, 3.563e-08, 3.408e-08, 3.265e-08,
  3.128e-08, 2.996e-08, 2.87e-08, 2.76e-08, 2.657e-08, 2.558e-08,
  2.467e-08, 2.385e-08, 2.307e-08, 2.234e-08, 2.168e-08, 2.108e-08,
  2.05e-08, 1.998e-08, 1.947e-08, 1.902e-08, 1.86e-08, 1.819e-08,
  1.782e-08
};

static double clo[121] = {
  7.419e-15, 1.061e-14, 1.518e-14, 2.195e-14, 3.175e-14, 4.666e-14,
  6.872e-14, 1.03e-13, 1.553e-13, 2.375e-13, 3.664e-13, 5.684e-13,
  8.915e-13, 1.402e-12, 2.269e-12, 4.125e-12, 7.501e-12, 1.257e-11,
  2.048e-11, 3.338e-11, 5.44e-11, 8.846e-11, 1.008e-10, 1.082e-10,
  1.157e-10, 1.232e-10, 1.312e-10, 1.539e-10, 1.822e-10, 2.118e-10,
  2.387e-10, 2.687e-10, 2.875e-10, 3.031e-10, 3.23e-10, 3.648e-10,
  4.117e-10, 4.477e-10, 4.633e-10, 4.794e-10, 4.95e-10, 5.104e-10,
  5.259e-10, 5.062e-10, 4.742e-10, 4.443e-10, 4.051e-10, 3.659e-10,
  3.305e-10, 2.911e-10, 2.54e-10, 2.215e-10, 1.927e-10, 1.675e-10,
  1.452e-10, 1.259e-10, 1.09e-10, 9.416e-11, 8.119e-11, 6.991e-11,
  6.015e-11, 5.163e-11, 4.43e-11, 3.789e-11, 3.24e-11, 2.769e-11,
  2.361e-11, 2.011e-11, 1.71e-11, 1.453e-11, 1.233e-11, 1.045e-11,
  8.851e-12, 7.48e-12, 6.316e-12, 5.326e-12, 4.487e-12, 3.778e-12,
  3.176e-12, 2.665e-12, 2.234e-12, 1.87e-12, 1.563e-12, 1.304e-12,
  1.085e-12, 9.007e-13, 7.468e-13, 6.179e-13, 5.092e-13, 4.188e-13,
  3.442e-13, 2.816e-13, 2.304e-13, 1.885e-13, 1.542e-13, 1.263e-13,
  1.035e-13, 8.5e-14, 7.004e-14, 5.783e-14, 4.795e-14, 4.007e-14,
  3.345e-14, 2.792e-14, 2.33e-14, 1.978e-14, 1.686e-14, 1.438e-14,
  1.234e-14, 1.07e-14, 9.312e-15, 8.131e-15, 7.164e-15, 6.367e-15,
  5.67e-15, 5.088e-15, 4.565e-15, 4.138e-15, 3.769e-15, 3.432e-15,
  3.148e-15
};

static double clono2[121] = {
  1.011e-13, 1.515e-13, 2.272e-13, 3.446e-13, 5.231e-13, 8.085e-13,
  1.253e-12, 1.979e-12, 3.149e-12, 5.092e-12, 8.312e-12, 1.366e-11,
  2.272e-11, 3.791e-11, 6.209e-11, 9.101e-11, 1.334e-10, 1.951e-10,
  2.853e-10, 3.94e-10, 4.771e-10, 5.771e-10, 6.675e-10, 7.665e-10,
  8.504e-10, 8.924e-10, 9.363e-10, 8.923e-10, 8.411e-10, 7.646e-10,
  6.525e-10, 5.576e-10, 4.398e-10, 3.403e-10, 2.612e-10, 1.915e-10,
  1.407e-10, 1.028e-10, 7.455e-11, 5.42e-11, 3.708e-11, 2.438e-11,
  1.618e-11, 1.075e-11, 7.17e-12, 4.784e-12, 3.205e-12, 2.147e-12,
  1.44e-12, 9.654e-13, 6.469e-13, 4.332e-13, 2.891e-13, 1.926e-13,
  1.274e-13, 8.422e-14, 5.547e-14, 3.636e-14, 2.368e-14, 1.536e-14,
  9.937e-15, 6.39e-15, 4.101e-15, 2.61e-15, 1.659e-15, 1.052e-15,
  6.638e-16, 4.172e-16, 2.61e-16, 1.63e-16, 1.013e-16, 6.275e-17,
  3.879e-17, 2.383e-17, 1.461e-17, 8.918e-18, 5.43e-18, 3.301e-18,
  1.997e-18, 1.203e-18, 7.216e-19, 4.311e-19, 2.564e-19, 1.519e-19,
  8.911e-20, 5.203e-20, 3.026e-20, 1.748e-20, 9.99e-21, 5.673e-21,
  3.215e-21, 1.799e-21, 1.006e-21, 5.628e-22, 3.146e-22, 1.766e-22,
  9.94e-23, 5.614e-23, 3.206e-23, 1.841e-23, 1.071e-23, 6.366e-24,
  3.776e-24, 2.238e-24, 1.326e-24, 8.253e-25, 5.201e-25, 3.279e-25,
  2.108e-25, 1.395e-25, 9.326e-26, 6.299e-26, 4.365e-26, 3.104e-26,
  2.219e-26, 1.621e-26, 1.185e-26, 8.92e-27, 6.804e-27, 5.191e-27,
  4.041e-27
};

static double co[121] = {
  1.907e-07, 1.553e-07, 1.362e-07, 1.216e-07, 1.114e-07, 1.036e-07,
  9.737e-08, 9.152e-08, 8.559e-08, 7.966e-08, 7.277e-08, 6.615e-08,
  5.884e-08, 5.22e-08, 4.699e-08, 4.284e-08, 3.776e-08, 3.274e-08,
  2.845e-08, 2.479e-08, 2.246e-08, 2.054e-08, 1.991e-08, 1.951e-08,
  1.94e-08, 2.009e-08, 2.1e-08, 2.201e-08, 2.322e-08, 2.45e-08,
  2.602e-08, 2.73e-08, 2.867e-08, 2.998e-08, 3.135e-08, 3.255e-08,
  3.352e-08, 3.426e-08, 3.484e-08, 3.53e-08, 3.593e-08, 3.671e-08,
  3.759e-08, 3.945e-08, 4.192e-08, 4.49e-08, 5.03e-08, 5.703e-08,
  6.538e-08, 7.878e-08, 9.644e-08, 1.196e-07, 1.498e-07, 1.904e-07,
  2.422e-07, 3.055e-07, 3.804e-07, 4.747e-07, 5.899e-07, 7.272e-07,
  8.91e-07, 1.071e-06, 1.296e-06, 1.546e-06, 1.823e-06, 2.135e-06,
  2.44e-06, 2.714e-06, 2.967e-06, 3.189e-06, 3.391e-06, 3.58e-06,
  3.773e-06, 4.022e-06, 4.346e-06, 4.749e-06, 5.199e-06, 5.668e-06,
  6.157e-06, 6.688e-06, 7.254e-06, 7.867e-06, 8.539e-06, 9.26e-06,
  1.009e-05, 1.119e-05, 1.228e-05, 1.365e-05, 1.506e-05, 1.641e-05,
  1.784e-05, 1.952e-05, 2.132e-05, 2.323e-05, 2.531e-05, 2.754e-05,
  3.047e-05, 3.459e-05, 3.922e-05, 4.439e-05, 4.825e-05, 5.077e-05,
  5.34e-05, 5.618e-05, 5.909e-05, 6.207e-05, 6.519e-05, 6.845e-05,
  6.819e-05, 6.726e-05, 6.622e-05, 6.512e-05, 6.671e-05, 6.862e-05,
  7.048e-05, 7.264e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05
};

static double cof2[121] = {
  7.5e-14, 1.055e-13, 1.485e-13, 2.111e-13, 3.001e-13, 4.333e-13,
  6.269e-13, 9.221e-13, 1.364e-12, 2.046e-12, 3.093e-12, 4.703e-12,
  7.225e-12, 1.113e-11, 1.66e-11, 2.088e-11, 2.626e-11, 3.433e-11,
  4.549e-11, 5.886e-11, 7.21e-11, 8.824e-11, 1.015e-10, 1.155e-10,
  1.288e-10, 1.388e-10, 1.497e-10, 1.554e-10, 1.606e-10, 1.639e-10,
  1.64e-10, 1.64e-10, 1.596e-10, 1.542e-10, 1.482e-10, 1.382e-10,
  1.289e-10, 1.198e-10, 1.109e-10, 1.026e-10, 9.484e-11, 8.75e-11,
  8.086e-11, 7.49e-11, 6.948e-11, 6.446e-11, 5.961e-11, 5.505e-11,
  5.085e-11, 4.586e-11, 4.1e-11, 3.665e-11, 3.235e-11, 2.842e-11,
  2.491e-11, 2.11e-11, 1.769e-11, 1.479e-11, 1.197e-11, 9.631e-12,
  7.74e-12, 6.201e-12, 4.963e-12, 3.956e-12, 3.151e-12, 2.507e-12,
  1.99e-12, 1.576e-12, 1.245e-12, 9.83e-13, 7.742e-13, 6.088e-13,
  4.782e-13, 3.745e-13, 2.929e-13, 2.286e-13, 1.782e-13, 1.388e-13,
  1.079e-13, 8.362e-14, 6.471e-14, 4.996e-14, 3.85e-14, 2.96e-14,
  2.265e-14, 1.729e-14, 1.317e-14, 9.998e-15, 7.549e-15, 5.683e-15,
  4.273e-15, 3.193e-15, 2.385e-15, 1.782e-15, 1.331e-15, 9.957e-16,
  7.461e-16, 5.601e-16, 4.228e-16, 3.201e-16, 2.438e-16, 1.878e-16,
  1.445e-16, 1.111e-16, 8.544e-17, 6.734e-17, 5.341e-17, 4.237e-17,
  3.394e-17, 2.759e-17, 2.254e-17, 1.851e-17, 1.54e-17, 1.297e-17,
  1.096e-17, 9.365e-18, 8e-18, 6.938e-18, 6.056e-18, 5.287e-18,
  4.662e-18
};

static double f11[121] = {
  2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10,
  2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.635e-10, 2.536e-10,
  2.44e-10, 2.348e-10, 2.258e-10, 2.153e-10, 2.046e-10, 1.929e-10,
  1.782e-10, 1.648e-10, 1.463e-10, 1.291e-10, 1.1e-10, 8.874e-11,
  7.165e-11, 5.201e-11, 3.744e-11, 2.577e-11, 1.64e-11, 1.048e-11,
  5.993e-12, 3.345e-12, 1.839e-12, 9.264e-13, 4.688e-13, 2.329e-13,
  1.129e-13, 5.505e-14, 2.825e-14, 1.492e-14, 7.997e-15, 5.384e-15,
  3.988e-15, 2.955e-15, 2.196e-15, 1.632e-15, 1.214e-15, 9.025e-16,
  6.708e-16, 4.984e-16, 3.693e-16, 2.733e-16, 2.013e-16, 1.481e-16,
  1.087e-16, 7.945e-17, 5.782e-17, 4.195e-17, 3.038e-17, 2.19e-17,
  1.577e-17, 1.128e-17, 8.063e-18, 5.753e-18, 4.09e-18, 2.899e-18,
  2.048e-18, 1.444e-18, 1.015e-18, 7.12e-19, 4.985e-19, 3.474e-19,
  2.417e-19, 1.677e-19, 1.161e-19, 8.029e-20, 5.533e-20, 3.799e-20,
  2.602e-20, 1.776e-20, 1.209e-20, 8.202e-21, 5.522e-21, 3.707e-21,
  2.48e-21, 1.652e-21, 1.091e-21, 7.174e-22, 4.709e-22, 3.063e-22,
  1.991e-22, 1.294e-22, 8.412e-23, 5.483e-23, 3.581e-23, 2.345e-23,
  1.548e-23, 1.027e-23, 6.869e-24, 4.673e-24, 3.173e-24, 2.153e-24,
  1.461e-24, 1.028e-24, 7.302e-25, 5.188e-25, 3.739e-25, 2.753e-25,
  2.043e-25, 1.528e-25, 1.164e-25, 9.041e-26, 7.051e-26, 5.587e-26,
  4.428e-26, 3.588e-26, 2.936e-26, 2.402e-26, 1.995e-26
};

static double f12[121] = {
  5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10,
  5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.429e-10, 5.291e-10,
  5.155e-10, 5.022e-10, 4.893e-10, 4.772e-10, 4.655e-10, 4.497e-10,
  4.249e-10, 4.015e-10, 3.632e-10, 3.261e-10, 2.858e-10, 2.408e-10,
  2.03e-10, 1.685e-10, 1.4e-10, 1.163e-10, 9.65e-11, 8.02e-11, 6.705e-11,
  5.624e-11, 4.764e-11, 4.249e-11, 3.792e-11, 3.315e-11, 2.819e-11,
  2.4e-11, 1.999e-11, 1.64e-11, 1.352e-11, 1.14e-11, 9.714e-12,
  8.28e-12, 7.176e-12, 6.251e-12, 5.446e-12, 4.72e-12, 4.081e-12,
  3.528e-12, 3.08e-12, 2.699e-12, 2.359e-12, 2.111e-12, 1.901e-12,
  1.709e-12, 1.534e-12, 1.376e-12, 1.233e-12, 1.103e-12, 9.869e-13,
  8.808e-13, 7.859e-13, 7.008e-13, 6.241e-13, 5.553e-13, 4.935e-13,
  4.383e-13, 3.889e-13, 3.447e-13, 3.054e-13, 2.702e-13, 2.389e-13,
  2.11e-13, 1.862e-13, 1.643e-13, 1.448e-13, 1.274e-13, 1.121e-13,
  9.844e-14, 8.638e-14, 7.572e-14, 6.62e-14, 5.782e-14, 5.045e-14,
  4.394e-14, 3.817e-14, 3.311e-14, 2.87e-14, 2.48e-14, 2.142e-14,
  1.851e-14, 1.599e-14, 1.383e-14, 1.196e-14, 1.036e-14, 9e-15,
  7.828e-15, 6.829e-15, 5.992e-15, 5.254e-15, 4.606e-15, 4.037e-15,
  3.583e-15, 3.19e-15, 2.841e-15, 2.542e-15, 2.291e-15, 2.07e-15,
  1.875e-15, 1.71e-15, 1.57e-15, 1.442e-15, 1.333e-15, 1.232e-15,
  1.147e-15, 1.071e-15, 1.001e-15, 9.396e-16
};

static double f14[121] = {
  9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11,
  9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 8.91e-11, 8.73e-11, 8.46e-11,
  8.19e-11, 7.92e-11, 7.74e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11
};

static double f22[121] = {
  1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10,
  1.4e-10, 1.4e-10, 1.4e-10, 1.372e-10, 1.317e-10, 1.235e-10, 1.153e-10,
  1.075e-10, 1.002e-10, 9.332e-11, 8.738e-11, 8.194e-11, 7.7e-11,
  7.165e-11, 6.753e-11, 6.341e-11, 5.971e-11, 5.6e-11, 5.229e-11,
  4.859e-11, 4.488e-11, 4.118e-11, 3.83e-11, 3.568e-11, 3.308e-11,
  3.047e-11, 2.82e-11, 2.594e-11, 2.409e-11, 2.237e-11, 2.065e-11,
  1.894e-11, 1.771e-11, 1.647e-11, 1.532e-11, 1.416e-11, 1.332e-11,
  1.246e-11, 1.161e-11, 1.087e-11, 1.017e-11, 9.471e-12, 8.853e-12,
  8.235e-12, 7.741e-12, 7.247e-12, 6.836e-12, 6.506e-12, 6.176e-12,
  5.913e-12, 5.65e-12, 5.419e-12, 5.221e-12, 5.024e-12, 4.859e-12,
  4.694e-12, 4.546e-12, 4.414e-12, 4.282e-12, 4.15e-12, 4.019e-12,
  3.903e-12, 3.805e-12, 3.706e-12, 3.607e-12, 3.508e-12, 3.41e-12,
  3.31e-12, 3.212e-12, 3.129e-12, 3.047e-12, 2.964e-12, 2.882e-12,
  2.8e-12, 2.734e-12, 2.668e-12, 2.602e-12, 2.537e-12, 2.471e-12,
  2.421e-12, 2.372e-12, 2.322e-12, 2.273e-12, 2.224e-12, 2.182e-12,
  2.141e-12, 2.1e-12, 2.059e-12, 2.018e-12, 1.977e-12, 1.935e-12,
  1.894e-12, 1.853e-12, 1.812e-12, 1.77e-12, 1.73e-12, 1.688e-12,
  1.647e-12, 1.606e-12, 1.565e-12, 1.524e-12, 1.483e-12, 1.441e-12,
  1.4e-12, 1.359e-12, 1.317e-12, 1.276e-12, 1.235e-12, 1.194e-12,
  1.153e-12, 1.112e-12, 1.071e-12, 1.029e-12, 9.883e-13
};

static double h2o[121] = {
  0.01166, 0.008269, 0.005742, 0.003845, 0.00277, 0.001897, 0.001272,
  0.000827, 0.000539, 0.0003469, 0.0001579, 3.134e-05, 1.341e-05,
  6.764e-06, 4.498e-06, 3.703e-06, 3.724e-06, 3.899e-06, 4.002e-06,
  4.122e-06, 4.277e-06, 4.438e-06, 4.558e-06, 4.673e-06, 4.763e-06,
  4.809e-06, 4.856e-06, 4.936e-06, 5.021e-06, 5.114e-06, 5.222e-06,
  5.331e-06, 5.414e-06, 5.488e-06, 5.563e-06, 5.633e-06, 5.704e-06,
  5.767e-06, 5.819e-06, 5.872e-06, 5.914e-06, 5.949e-06, 5.984e-06,
  6.015e-06, 6.044e-06, 6.073e-06, 6.104e-06, 6.136e-06, 6.167e-06,
  6.189e-06, 6.208e-06, 6.226e-06, 6.212e-06, 6.185e-06, 6.158e-06,
  6.114e-06, 6.066e-06, 6.018e-06, 5.877e-06, 5.728e-06, 5.582e-06,
  5.437e-06, 5.296e-06, 5.156e-06, 5.02e-06, 4.886e-06, 4.754e-06,
  4.625e-06, 4.498e-06, 4.374e-06, 4.242e-06, 4.096e-06, 3.955e-06,
  3.817e-06, 3.683e-06, 3.491e-06, 3.204e-06, 2.94e-06, 2.696e-06,
  2.47e-06, 2.252e-06, 2.019e-06, 1.808e-06, 1.618e-06, 1.445e-06,
  1.285e-06, 1.105e-06, 9.489e-07, 8.121e-07, 6.938e-07, 5.924e-07,
  5.04e-07, 4.288e-07, 3.648e-07, 3.103e-07, 2.642e-07, 2.252e-07,
  1.921e-07, 1.643e-07, 1.408e-07, 1.211e-07, 1.048e-07, 9.063e-08,
  7.835e-08, 6.774e-08, 5.936e-08, 5.221e-08, 4.592e-08, 4.061e-08,
  3.62e-08, 3.236e-08, 2.902e-08, 2.62e-08, 2.383e-08, 2.171e-08,
  1.989e-08, 1.823e-08, 1.684e-08, 1.562e-08, 1.449e-08, 1.351e-08
};

static double h2o2[121] = {
  1.779e-10, 7.938e-10, 8.953e-10, 8.032e-10, 6.564e-10, 5.159e-10,
  4.003e-10, 3.026e-10, 2.222e-10, 1.58e-10, 1.044e-10, 6.605e-11,
  3.413e-11, 1.453e-11, 1.062e-11, 1.009e-11, 9.597e-12, 1.175e-11,
  1.572e-11, 2.091e-11, 2.746e-11, 3.603e-11, 4.791e-11, 6.387e-11,
  8.239e-11, 1.007e-10, 1.23e-10, 1.363e-10, 1.489e-10, 1.585e-10,
  1.608e-10, 1.632e-10, 1.576e-10, 1.502e-10, 1.423e-10, 1.302e-10,
  1.192e-10, 1.085e-10, 9.795e-11, 8.854e-11, 8.057e-11, 7.36e-11,
  6.736e-11, 6.362e-11, 6.087e-11, 5.825e-11, 5.623e-11, 5.443e-11,
  5.27e-11, 5.098e-11, 4.931e-11, 4.769e-11, 4.611e-11, 4.458e-11,
  4.308e-11, 4.102e-11, 3.887e-11, 3.682e-11, 3.521e-11, 3.369e-11,
  3.224e-11, 3.082e-11, 2.946e-11, 2.814e-11, 2.687e-11, 2.566e-11,
  2.449e-11, 2.336e-11, 2.227e-11, 2.123e-11, 2.023e-11, 1.927e-11,
  1.835e-11, 1.746e-11, 1.661e-11, 1.58e-11, 1.502e-11, 1.428e-11,
  1.357e-11, 1.289e-11, 1.224e-11, 1.161e-11, 1.102e-11, 1.045e-11,
  9.895e-12, 9.369e-12, 8.866e-12, 8.386e-12, 7.922e-12, 7.479e-12,
  7.06e-12, 6.656e-12, 6.274e-12, 5.914e-12, 5.575e-12, 5.257e-12,
  4.959e-12, 4.679e-12, 4.42e-12, 4.178e-12, 3.954e-12, 3.75e-12,
  3.557e-12, 3.372e-12, 3.198e-12, 3.047e-12, 2.908e-12, 2.775e-12,
  2.653e-12, 2.544e-12, 2.442e-12, 2.346e-12, 2.26e-12, 2.183e-12,
  2.11e-12, 2.044e-12, 1.98e-12, 1.924e-12, 1.871e-12, 1.821e-12,
  1.775e-12
};

static double hcn[121] = {
  5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10,
  5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.498e-10, 5.495e-10, 5.493e-10,
  5.49e-10, 5.488e-10, 4.717e-10, 3.946e-10, 3.174e-10, 2.4e-10,
  1.626e-10, 1.619e-10, 1.612e-10, 1.602e-10, 1.593e-10, 1.582e-10,
  1.572e-10, 1.56e-10, 1.549e-10, 1.539e-10, 1.53e-10, 1.519e-10,
  1.506e-10, 1.487e-10, 1.467e-10, 1.449e-10, 1.43e-10, 1.413e-10,
  1.397e-10, 1.382e-10, 1.368e-10, 1.354e-10, 1.337e-10, 1.315e-10,
  1.292e-10, 1.267e-10, 1.241e-10, 1.215e-10, 1.19e-10, 1.165e-10,
  1.141e-10, 1.118e-10, 1.096e-10, 1.072e-10, 1.047e-10, 1.021e-10,
  9.968e-11, 9.739e-11, 9.539e-11, 9.339e-11, 9.135e-11, 8.898e-11,
  8.664e-11, 8.439e-11, 8.249e-11, 8.075e-11, 7.904e-11, 7.735e-11,
  7.565e-11, 7.399e-11, 7.245e-11, 7.109e-11, 6.982e-11, 6.863e-11,
  6.755e-11, 6.657e-11, 6.587e-11, 6.527e-11, 6.476e-11, 6.428e-11,
  6.382e-11, 6.343e-11, 6.307e-11, 6.272e-11, 6.238e-11, 6.205e-11,
  6.17e-11, 6.137e-11, 6.102e-11, 6.072e-11, 6.046e-11, 6.03e-11,
  6.018e-11, 6.01e-11, 6.001e-11, 5.992e-11, 5.984e-11, 5.975e-11,
  5.967e-11, 5.958e-11, 5.95e-11, 5.941e-11, 5.933e-11, 5.925e-11,
  5.916e-11, 5.908e-11, 5.899e-11, 5.891e-11, 5.883e-11, 5.874e-11,
  5.866e-11, 5.858e-11, 5.85e-11, 5.841e-11, 5.833e-11, 5.825e-11,
  5.817e-11, 5.808e-11, 5.8e-11, 5.792e-11, 5.784e-11
};

static double hno3[121] = {
  1.809e-10, 7.234e-10, 5.899e-10, 4.342e-10, 3.277e-10, 2.661e-10,
  2.35e-10, 2.267e-10, 2.389e-10, 2.651e-10, 3.255e-10, 4.099e-10,
  5.42e-10, 6.978e-10, 8.807e-10, 1.112e-09, 1.405e-09, 2.04e-09,
  3.111e-09, 4.5e-09, 5.762e-09, 7.37e-09, 7.852e-09, 8.109e-09,
  8.067e-09, 7.554e-09, 7.076e-09, 6.268e-09, 5.524e-09, 4.749e-09,
  3.909e-09, 3.223e-09, 2.517e-09, 1.942e-09, 1.493e-09, 1.122e-09,
  8.449e-10, 6.361e-10, 4.787e-10, 3.611e-10, 2.804e-10, 2.215e-10,
  1.758e-10, 1.441e-10, 1.197e-10, 9.953e-11, 8.505e-11, 7.334e-11,
  6.325e-11, 5.625e-11, 5.058e-11, 4.548e-11, 4.122e-11, 3.748e-11,
  3.402e-11, 3.088e-11, 2.8e-11, 2.536e-11, 2.293e-11, 2.072e-11,
  1.871e-11, 1.687e-11, 1.52e-11, 1.368e-11, 1.23e-11, 1.105e-11,
  9.922e-12, 8.898e-12, 7.972e-12, 7.139e-12, 6.385e-12, 5.708e-12,
  5.099e-12, 4.549e-12, 4.056e-12, 3.613e-12, 3.216e-12, 2.862e-12,
  2.544e-12, 2.259e-12, 2.004e-12, 1.776e-12, 1.572e-12, 1.391e-12,
  1.227e-12, 1.082e-12, 9.528e-13, 8.379e-13, 7.349e-13, 6.436e-13,
  5.634e-13, 4.917e-13, 4.291e-13, 3.745e-13, 3.267e-13, 2.854e-13,
  2.494e-13, 2.181e-13, 1.913e-13, 1.68e-13, 1.479e-13, 1.31e-13,
  1.159e-13, 1.025e-13, 9.067e-14, 8.113e-14, 7.281e-14, 6.535e-14,
  5.892e-14, 5.348e-14, 4.867e-14, 4.439e-14, 4.073e-14, 3.76e-14,
  3.476e-14, 3.229e-14, 3e-14, 2.807e-14, 2.635e-14, 2.473e-14,
  2.332e-14
};

static double hno4[121] = {
  6.118e-12, 3.594e-12, 2.807e-12, 3.04e-12, 4.458e-12, 7.986e-12,
  1.509e-11, 2.661e-11, 3.738e-11, 4.652e-11, 4.429e-11, 3.992e-11,
  3.347e-11, 3.005e-11, 3.173e-11, 4.055e-11, 5.812e-11, 8.489e-11,
  1.19e-10, 1.482e-10, 1.766e-10, 2.103e-10, 2.35e-10, 2.598e-10,
  2.801e-10, 2.899e-10, 3e-10, 2.817e-10, 2.617e-10, 2.332e-10,
  1.933e-10, 1.605e-10, 1.232e-10, 9.285e-11, 6.941e-11, 4.951e-11,
  3.539e-11, 2.402e-11, 1.522e-11, 9.676e-12, 6.056e-12, 3.745e-12,
  2.34e-12, 1.463e-12, 9.186e-13, 5.769e-13, 3.322e-13, 1.853e-13,
  1.035e-13, 7.173e-14, 5.382e-14, 4.036e-14, 3.401e-14, 2.997e-14,
  2.635e-14, 2.316e-14, 2.034e-14, 1.783e-14, 1.56e-14, 1.363e-14,
  1.19e-14, 1.037e-14, 9.032e-15, 7.846e-15, 6.813e-15, 5.912e-15,
  5.121e-15, 4.431e-15, 3.829e-15, 3.306e-15, 2.851e-15, 2.456e-15,
  2.114e-15, 1.816e-15, 1.559e-15, 1.337e-15, 1.146e-15, 9.811e-16,
  8.389e-16, 7.162e-16, 6.109e-16, 5.203e-16, 4.425e-16, 3.76e-16,
  3.184e-16, 2.692e-16, 2.274e-16, 1.917e-16, 1.61e-16, 1.35e-16,
  1.131e-16, 9.437e-17, 7.874e-17, 6.57e-17, 5.481e-17, 4.579e-17,
  3.828e-17, 3.204e-17, 2.691e-17, 2.264e-17, 1.912e-17, 1.626e-17,
  1.382e-17, 1.174e-17, 9.972e-18, 8.603e-18, 7.45e-18, 6.453e-18,
  5.623e-18, 4.944e-18, 4.361e-18, 3.859e-18, 3.443e-18, 3.096e-18,
  2.788e-18, 2.528e-18, 2.293e-18, 2.099e-18, 1.929e-18, 1.773e-18,
  1.64e-18
};

static double hocl[121] = {
  1.056e-12, 1.194e-12, 1.35e-12, 1.531e-12, 1.737e-12, 1.982e-12,
  2.263e-12, 2.599e-12, 2.991e-12, 3.459e-12, 4.012e-12, 4.662e-12,
  5.438e-12, 6.35e-12, 7.425e-12, 8.686e-12, 1.016e-11, 1.188e-11,
  1.389e-11, 1.659e-11, 2.087e-11, 2.621e-11, 3.265e-11, 4.064e-11,
  4.859e-11, 5.441e-11, 6.09e-11, 6.373e-11, 6.611e-11, 6.94e-11,
  7.44e-11, 7.97e-11, 8.775e-11, 9.722e-11, 1.064e-10, 1.089e-10,
  1.114e-10, 1.106e-10, 1.053e-10, 1.004e-10, 9.006e-11, 7.778e-11,
  6.739e-11, 5.636e-11, 4.655e-11, 3.845e-11, 3.042e-11, 2.368e-11,
  1.845e-11, 1.442e-11, 1.127e-11, 8.814e-12, 6.544e-12, 4.763e-12,
  3.449e-12, 2.612e-12, 1.999e-12, 1.526e-12, 1.16e-12, 8.793e-13,
  6.655e-13, 5.017e-13, 3.778e-13, 2.829e-13, 2.117e-13, 1.582e-13,
  1.178e-13, 8.755e-14, 6.486e-14, 4.799e-14, 3.54e-14, 2.606e-14,
  1.916e-14, 1.403e-14, 1.026e-14, 7.48e-15, 5.446e-15, 3.961e-15,
  2.872e-15, 2.076e-15, 1.498e-15, 1.077e-15, 7.726e-16, 5.528e-16,
  3.929e-16, 2.785e-16, 1.969e-16, 1.386e-16, 9.69e-17, 6.747e-17,
  4.692e-17, 3.236e-17, 2.232e-17, 1.539e-17, 1.061e-17, 7.332e-18,
  5.076e-18, 3.522e-18, 2.461e-18, 1.726e-18, 1.22e-18, 8.75e-19,
  6.264e-19, 4.482e-19, 3.207e-19, 2.368e-19, 1.762e-19, 1.312e-19,
  9.891e-20, 7.595e-20, 5.87e-20, 4.567e-20, 3.612e-20, 2.904e-20,
  2.343e-20, 1.917e-20, 1.568e-20, 1.308e-20, 1.1e-20, 9.25e-21,
  7.881e-21
};

static double n2o[121] = {
  3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07,
  3.17e-07, 3.17e-07, 3.17e-07, 3.124e-07, 3.077e-07, 3.03e-07,
  2.984e-07, 2.938e-07, 2.892e-07, 2.847e-07, 2.779e-07, 2.705e-07,
  2.631e-07, 2.557e-07, 2.484e-07, 2.345e-07, 2.201e-07, 2.01e-07,
  1.754e-07, 1.532e-07, 1.329e-07, 1.154e-07, 1.003e-07, 8.735e-08,
  7.617e-08, 6.512e-08, 5.547e-08, 4.709e-08, 3.915e-08, 3.259e-08,
  2.738e-08, 2.327e-08, 1.98e-08, 1.711e-08, 1.493e-08, 1.306e-08,
  1.165e-08, 1.049e-08, 9.439e-09, 8.375e-09, 7.391e-09, 6.525e-09,
  5.759e-09, 5.083e-09, 4.485e-09, 3.953e-09, 3.601e-09, 3.27e-09,
  2.975e-09, 2.757e-09, 2.556e-09, 2.37e-09, 2.195e-09, 2.032e-09,
  1.912e-09, 1.79e-09, 1.679e-09, 1.572e-09, 1.482e-09, 1.402e-09,
  1.326e-09, 1.254e-09, 1.187e-09, 1.127e-09, 1.071e-09, 1.02e-09,
  9.673e-10, 9.193e-10, 8.752e-10, 8.379e-10, 8.017e-10, 7.66e-10,
  7.319e-10, 7.004e-10, 6.721e-10, 6.459e-10, 6.199e-10, 5.942e-10,
  5.703e-10, 5.488e-10, 5.283e-10, 5.082e-10, 4.877e-10, 4.696e-10,
  4.52e-10, 4.355e-10, 4.198e-10, 4.039e-10, 3.888e-10, 3.754e-10,
  3.624e-10, 3.499e-10, 3.381e-10, 3.267e-10, 3.163e-10, 3.058e-10,
  2.959e-10, 2.864e-10, 2.77e-10, 2.686e-10, 2.604e-10, 2.534e-10,
  2.462e-10, 2.386e-10, 2.318e-10, 2.247e-10, 2.189e-10, 2.133e-10,
  2.071e-10, 2.014e-10, 1.955e-10, 1.908e-10, 1.86e-10, 1.817e-10
};

static double n2o5[121] = {
  1.231e-11, 3.035e-12, 1.702e-12, 9.877e-13, 8.081e-13, 9.039e-13,
  1.169e-12, 1.474e-12, 1.651e-12, 1.795e-12, 1.998e-12, 2.543e-12,
  4.398e-12, 7.698e-12, 1.28e-11, 2.131e-11, 3.548e-11, 5.894e-11,
  7.645e-11, 1.089e-10, 1.391e-10, 1.886e-10, 2.386e-10, 2.986e-10,
  3.487e-10, 3.994e-10, 4.5e-10, 4.6e-10, 4.591e-10, 4.1e-10, 3.488e-10,
  2.846e-10, 2.287e-10, 1.696e-10, 1.011e-10, 6.428e-11, 4.324e-11,
  2.225e-11, 6.214e-12, 3.608e-12, 8.793e-13, 4.491e-13, 1.04e-13,
  6.1e-14, 3.436e-14, 6.671e-15, 1.171e-15, 5.848e-16, 1.212e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16
};

static double nh3[121] = {
  1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
  1e-10, 1e-10, 1e-10, 1e-10, 9.444e-11, 8.488e-11, 7.241e-11, 5.785e-11,
  4.178e-11, 3.018e-11, 2.18e-11, 1.574e-11, 1.137e-11, 8.211e-12,
  5.973e-12, 4.327e-12, 3.118e-12, 2.234e-12, 1.573e-12, 1.04e-12,
  6.762e-13, 4.202e-13, 2.406e-13, 1.335e-13, 6.938e-14, 3.105e-14,
  1.609e-14, 1.033e-14, 6.432e-15, 4.031e-15, 2.555e-15, 1.656e-15,
  1.115e-15, 7.904e-16, 5.63e-16, 4.048e-16, 2.876e-16, 2.004e-16,
  1.356e-16, 9.237e-17, 6.235e-17, 4.223e-17, 3.009e-17, 2.328e-17,
  2.002e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17
};

static double no[121] = {
  2.586e-10, 4.143e-11, 1.566e-11, 9.591e-12, 8.088e-12, 8.462e-12,
  1.013e-11, 1.328e-11, 1.855e-11, 2.678e-11, 3.926e-11, 5.464e-11,
  7.012e-11, 8.912e-11, 1.127e-10, 1.347e-10, 1.498e-10, 1.544e-10,
  1.602e-10, 1.824e-10, 2.078e-10, 2.366e-10, 2.691e-10, 5.141e-10,
  8.259e-10, 1.254e-09, 1.849e-09, 2.473e-09, 3.294e-09, 4.16e-09,
  5.095e-09, 6.11e-09, 6.93e-09, 7.888e-09, 8.903e-09, 9.713e-09,
  1.052e-08, 1.115e-08, 1.173e-08, 1.21e-08, 1.228e-08, 1.239e-08,
  1.231e-08, 1.213e-08, 1.192e-08, 1.138e-08, 1.085e-08, 1.008e-08,
  9.224e-09, 8.389e-09, 7.262e-09, 6.278e-09, 5.335e-09, 4.388e-09,
  3.589e-09, 2.761e-09, 2.129e-09, 1.633e-09, 1.243e-09, 9.681e-10,
  8.355e-10, 7.665e-10, 7.442e-10, 8.584e-10, 9.732e-10, 1.063e-09,
  1.163e-09, 1.286e-09, 1.472e-09, 1.707e-09, 2.032e-09, 2.474e-09,
  2.977e-09, 3.506e-09, 4.102e-09, 5.013e-09, 6.493e-09, 8.414e-09,
  1.077e-08, 1.367e-08, 1.777e-08, 2.625e-08, 3.926e-08, 5.545e-08,
  7.195e-08, 9.464e-08, 1.404e-07, 2.183e-07, 3.329e-07, 4.535e-07,
  6.158e-07, 8.187e-07, 1.075e-06, 1.422e-06, 1.979e-06, 2.71e-06,
  3.58e-06, 4.573e-06, 5.951e-06, 7.999e-06, 1.072e-05, 1.372e-05,
  1.697e-05, 2.112e-05, 2.643e-05, 3.288e-05, 3.994e-05, 4.794e-05,
  5.606e-05, 6.383e-05, 7.286e-05, 8.156e-05, 8.883e-05, 9.469e-05,
  9.848e-05, 0.0001023, 0.0001066, 0.0001115, 0.0001145, 0.0001142,
  0.0001133
};

static double no2[121] = {
  3.036e-09, 2.945e-10, 9.982e-11, 5.069e-11, 3.485e-11, 2.982e-11,
  2.947e-11, 3.164e-11, 3.714e-11, 4.586e-11, 6.164e-11, 8.041e-11,
  9.982e-11, 1.283e-10, 1.73e-10, 2.56e-10, 3.909e-10, 5.959e-10,
  9.081e-10, 1.384e-09, 1.788e-09, 2.189e-09, 2.686e-09, 3.091e-09,
  3.49e-09, 3.796e-09, 4.2e-09, 5.103e-09, 6.005e-09, 6.3e-09, 6.706e-09,
  7.07e-09, 7.434e-09, 7.663e-09, 7.788e-09, 7.8e-09, 7.597e-09,
  7.482e-09, 7.227e-09, 6.403e-09, 5.585e-09, 4.606e-09, 3.703e-09,
  2.984e-09, 2.183e-09, 1.48e-09, 8.441e-10, 5.994e-10, 3.799e-10,
  2.751e-10, 1.927e-10, 1.507e-10, 1.102e-10, 6.971e-11, 5.839e-11,
  3.904e-11, 3.087e-11, 2.176e-11, 1.464e-11, 1.209e-11, 8.497e-12,
  6.477e-12, 4.371e-12, 2.914e-12, 2.424e-12, 1.753e-12, 1.35e-12,
  9.417e-13, 6.622e-13, 5.148e-13, 3.841e-13, 3.446e-13, 3.01e-13,
  2.551e-13, 2.151e-13, 1.829e-13, 1.64e-13, 1.475e-13, 1.352e-13,
  1.155e-13, 9.963e-14, 9.771e-14, 9.577e-14, 9.384e-14, 9.186e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14
};

static double o3[121] = {
  2.218e-08, 3.394e-08, 3.869e-08, 4.219e-08, 4.501e-08, 4.778e-08,
  5.067e-08, 5.402e-08, 5.872e-08, 6.521e-08, 7.709e-08, 9.461e-08,
  1.269e-07, 1.853e-07, 2.723e-07, 3.964e-07, 5.773e-07, 8.2e-07,
  1.155e-06, 1.59e-06, 2.076e-06, 2.706e-06, 3.249e-06, 3.848e-06,
  4.459e-06, 4.986e-06, 5.573e-06, 5.958e-06, 6.328e-06, 6.661e-06,
  6.9e-06, 7.146e-06, 7.276e-06, 7.374e-06, 7.447e-06, 7.383e-06,
  7.321e-06, 7.161e-06, 6.879e-06, 6.611e-06, 6.216e-06, 5.765e-06,
  5.355e-06, 4.905e-06, 4.471e-06, 4.075e-06, 3.728e-06, 3.413e-06,
  3.125e-06, 2.856e-06, 2.607e-06, 2.379e-06, 2.17e-06, 1.978e-06,
  1.8e-06, 1.646e-06, 1.506e-06, 1.376e-06, 1.233e-06, 1.102e-06,
  9.839e-07, 8.771e-07, 7.814e-07, 6.947e-07, 6.102e-07, 5.228e-07,
    4.509e-07, 3.922e-07, 3.501e-07, 3.183e-07, 2.909e-07, 2.686e-07,
    2.476e-07, 2.284e-07, 2.109e-07, 2.003e-07, 2.013e-07, 2.022e-07,
    2.032e-07, 2.042e-07, 2.097e-07, 2.361e-07, 2.656e-07, 2.989e-07,
    3.37e-07, 3.826e-07, 4.489e-07, 5.26e-07, 6.189e-07, 7.312e-07,
    8.496e-07, 8.444e-07, 8.392e-07, 8.339e-07, 8.286e-07, 8.234e-07,
    8.181e-07, 8.129e-07, 8.077e-07, 8.026e-07, 6.918e-07, 5.176e-07,
    3.865e-07, 2.885e-07, 2.156e-07, 1.619e-07, 1.219e-07, 9.161e-08,
    6.972e-08, 5.399e-08, 3.498e-08, 2.111e-08, 1.322e-08, 8.482e-09,
    5.527e-09, 3.423e-09, 2.071e-09, 1.314e-09, 8.529e-10, 5.503e-10,
    3.665e-10
  };

  static double ocs[121] = {
    6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 5.997e-10,
    5.989e-10, 5.881e-10, 5.765e-10, 5.433e-10, 5.074e-10, 4.567e-10,
    4.067e-10, 3.601e-10, 3.093e-10, 2.619e-10, 2.232e-10, 1.805e-10,
    1.46e-10, 1.187e-10, 8.03e-11, 5.435e-11, 3.686e-11, 2.217e-11,
    1.341e-11, 8.756e-12, 4.511e-12, 2.37e-12, 1.264e-12, 8.28e-13,
    5.263e-13, 3.209e-13, 1.717e-13, 9.068e-14, 4.709e-14, 2.389e-14,
    1.236e-14, 1.127e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
    1.091e-14, 1.091e-14, 1.091e-14
  };

  static double sf6[121] = {
    4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12,
    4.103e-12, 4.103e-12, 4.103e-12, 4.087e-12, 4.064e-12, 4.023e-12,
    3.988e-12, 3.941e-12, 3.884e-12, 3.755e-12, 3.622e-12, 3.484e-12,
    3.32e-12, 3.144e-12, 2.978e-12, 2.811e-12, 2.653e-12, 2.489e-12,
    2.332e-12, 2.199e-12, 2.089e-12, 2.013e-12, 1.953e-12, 1.898e-12,
    1.859e-12, 1.826e-12, 1.798e-12, 1.776e-12, 1.757e-12, 1.742e-12,
    1.728e-12, 1.717e-12, 1.707e-12, 1.698e-12, 1.691e-12, 1.685e-12,
    1.679e-12, 1.675e-12, 1.671e-12, 1.668e-12, 1.665e-12, 1.663e-12,
    1.661e-12, 1.659e-12, 1.658e-12, 1.657e-12, 1.656e-12, 1.655e-12,
    1.654e-12, 1.653e-12, 1.653e-12, 1.652e-12, 1.652e-12, 1.652e-12,
    1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12,
    1.651e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
    1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12
  };

  static double so2[121] = {
    1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
    1e-10, 1e-10, 9.867e-11, 9.537e-11, 9e-11, 8.404e-11, 7.799e-11,
    7.205e-11, 6.616e-11, 6.036e-11, 5.475e-11, 5.007e-11, 4.638e-11,
    4.346e-11, 4.055e-11, 3.763e-11, 3.471e-11, 3.186e-11, 2.905e-11,
    2.631e-11, 2.358e-11, 2.415e-11, 2.949e-11, 3.952e-11, 5.155e-11,
    6.76e-11, 8.741e-11, 1.099e-10, 1.278e-10, 1.414e-10, 1.512e-10,
    1.607e-10, 1.699e-10, 1.774e-10, 1.832e-10, 1.871e-10, 1.907e-10,
    1.943e-10, 1.974e-10, 1.993e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10
  };

  static int ig_co2 = -999;

  double co2, *q[NG] = { NULL };

  int ig, ip, iw, iz;

  /* Find emitter index of CO2... */
  if (ig_co2 == -999)
    ig_co2 = find_emitter(ctl, "CO2");

  /* Identify variable... */
  for (ig = 0; ig < ctl->ng; ig++) {
    q[ig] = NULL;
    if (strcasecmp(ctl->emitter[ig], "C2H2") == 0)
      q[ig] = c2h2;
    if (strcasecmp(ctl->emitter[ig], "C2H6") == 0)
      q[ig] = c2h6;
    if (strcasecmp(ctl->emitter[ig], "CCl4") == 0)
      q[ig] = ccl4;
    if (strcasecmp(ctl->emitter[ig], "CH4") == 0)
      q[ig] = ch4;
    if (strcasecmp(ctl->emitter[ig], "ClO") == 0)
      q[ig] = clo;
    if (strcasecmp(ctl->emitter[ig], "ClONO2") == 0)
      q[ig] = clono2;
    if (strcasecmp(ctl->emitter[ig], "CO") == 0)
      q[ig] = co;
    if (strcasecmp(ctl->emitter[ig], "COF2") == 0)
      q[ig] = cof2;
    if (strcasecmp(ctl->emitter[ig], "F11") == 0)
      q[ig] = f11;
    if (strcasecmp(ctl->emitter[ig], "F12") == 0)
      q[ig] = f12;
    if (strcasecmp(ctl->emitter[ig], "F14") == 0)
      q[ig] = f14;
    if (strcasecmp(ctl->emitter[ig], "F22") == 0)
      q[ig] = f22;
    if (strcasecmp(ctl->emitter[ig], "H2O") == 0)
      q[ig] = h2o;
    if (strcasecmp(ctl->emitter[ig], "H2O2") == 0)
      q[ig] = h2o2;
    if (strcasecmp(ctl->emitter[ig], "HCN") == 0)
      q[ig] = hcn;
    if (strcasecmp(ctl->emitter[ig], "HNO3") == 0)
      q[ig] = hno3;
    if (strcasecmp(ctl->emitter[ig], "HNO4") == 0)
      q[ig] = hno4;
    if (strcasecmp(ctl->emitter[ig], "HOCl") == 0)
      q[ig] = hocl;
    if (strcasecmp(ctl->emitter[ig], "N2O") == 0)
      q[ig] = n2o;
    if (strcasecmp(ctl->emitter[ig], "N2O5") == 0)
      q[ig] = n2o5;
    if (strcasecmp(ctl->emitter[ig], "NH3") == 0)
      q[ig] = nh3;
    if (strcasecmp(ctl->emitter[ig], "NO") == 0)
      q[ig] = no;
    if (strcasecmp(ctl->emitter[ig], "NO2") == 0)
      q[ig] = no2;
    if (strcasecmp(ctl->emitter[ig], "O3") == 0)
      q[ig] = o3;
    if (strcasecmp(ctl->emitter[ig], "OCS") == 0)
      q[ig] = ocs;
    if (strcasecmp(ctl->emitter[ig], "SF6") == 0)
      q[ig] = sf6;
    if (strcasecmp(ctl->emitter[ig], "SO2") == 0)
      q[ig] = so2;
  }

  /* Loop over atmospheric data points... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Get altitude index... */
    iz = locate(z, 121, atm->z[ip]);

    /* Interpolate pressure... */
    atm->p[ip] = EXP(z[iz], pre[iz], z[iz + 1], pre[iz + 1], atm->z[ip]);

    /* Interpolate temperature... */
    atm->t[ip] = LIN(z[iz], tem[iz], z[iz + 1], tem[iz + 1], atm->z[ip]);

    /* Interpolate trace gases... */
    for (ig = 0; ig < ctl->ng; ig++)
      if (q[ig] != NULL)
        atm->q[ig][ip] =
          LIN(z[iz], q[ig][iz], z[iz + 1], q[ig][iz + 1], atm->z[ip]);
      else
        atm->q[ig][ip] = 0;

    /* Set CO2... */
    if (ig_co2 >= 0) {
      co2 =
        371.789948e-6 + 2.026214e-6 * (atm->time[ip] - 63158400.) / 31557600.;
      atm->q[ig_co2][ip] = co2;
    }

    /* Set extinction to zero... */
    for (iw = 0; iw < ctl->nw; iw++)
      atm->k[iw][ip] = 0;
  }
}
```

Here is the call graph for this function:



5.13.2.6 double ctmco2 (double *nu,* double *p,* double *t,* double *u*)

Compute carbon dioxide continuum (optical depth).

Definition at line 874 of file jurassic.c.

```
            {

  static double co2296[2001] = { 9.3388e-5, 9.7711e-5, 1.0224e-4, 1.0697e-4,
    1.1193e-4, 1.1712e-4, 1.2255e-4, 1.2824e-4, 1.3419e-4, 1.4043e-4,
    1.4695e-4, 1.5378e-4, 1.6094e-4, 1.6842e-4, 1.7626e-4, 1.8447e-4,
    1.9307e-4, 2.0207e-4, 2.1149e-4, 2.2136e-4, 2.3169e-4, 2.4251e-4,
    2.5384e-4, 2.657e-4, 2.7813e-4, 2.9114e-4, 3.0477e-4, 3.1904e-4,
    3.3399e-4, 3.4965e-4, 3.6604e-4, 3.8322e-4, 4.0121e-4, 4.2006e-4,
    4.398e-4, 4.6047e-4, 4.8214e-4, 5.0483e-4, 5.286e-4, 5.535e-4,
    5.7959e-4, 6.0693e-4, 6.3557e-4, 6.6558e-4, 6.9702e-4, 7.2996e-4,
    7.6449e-4, 8.0066e-4, 8.3856e-4, 8.7829e-4, 9.1991e-4, 9.6354e-4,
    .0010093, .0010572, .0011074, .00116, .0012152, .001273,
    .0013336, .0013972, .0014638, .0015336, .0016068, .0016835,
    .001764, .0018483, .0019367, .0020295, .0021267, .0022286,
    .0023355, .0024476, .0025652, .0026885, .0028178, .0029534,
    .0030956, .0032448, .0034012, .0035654, .0037375, .0039181,
    .0041076, .0043063, .0045148, .0047336, .0049632, .005204,
    .0054567, .0057219, .0060002, .0062923, .0065988, .0069204,
    .007258, .0076123, .0079842, .0083746, .0087844, .0092146,
    .0096663, .01014, .010638, .011161, .01171, .012286, .012891,
    .013527, .014194, .014895, .015631, .016404, .017217, .01807,
    .018966, .019908, .020897, .021936, .023028, .024176, .025382,
    .026649, .027981, .02938, .030851, .032397, .034023, .035732,
    .037528, .039416, .041402, .04349, .045685, .047994, .050422,
    .052975, .055661, .058486, .061458, .064584, .067873, .071334,
    .074975, .078807, .082839, .087082, .091549, .096249, .1012,
    .10641, .11189, .11767, .12375, .13015, .13689, .14399, .15147,
    .15935, .16765, .17639, .18561, .19531, .20554, .21632, .22769,
    .23967, .25229, .2656, .27964, .29443, .31004, .3265, .34386,
    .36218, .3815, .40188, .42339, .44609, .47004, .49533, .52202,
    .5502, .57995, .61137, .64455, .6796, .71663, .75574, .79707,
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      523.12, 462.24, 409.75, 364.34, 325., 290.73, 260.76, 234.46,
      211.28, 190.78, 172.61, 156.44, 142.01, 129.12, 117.57, 107.2,
      97.877, 89.47, 81.882, 75.021, 68.807, 63.171, 58.052, 53.396,
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      .20051, .18899, .17815, .16801, .15846, .14954, .14117, .13328,
      .12584
    };

    double xw, dw, ew, cw296, cw260, cw230, dt230, dt260, dt296, ctw, ctmpth;

    int iw, jw;

    /* Get CO2 continuum absorption... */
    xw = nu / 2 + 1;
    if (xw >= 1 && xw < 2001) {
      iw = (int) xw;
      jw = iw + 1;
      dw = xw - iw;
      ew = 1 - dw;
      cw296 = ew * co2296[iw - 1] + dw * co2296[jw - 1];
      cw260 = ew * co2260[iw - 1] + dw * co2260[jw - 1];
      cw230 = ew * co2230[iw - 1] + dw * co2230[jw - 1];
      dt230 = t - 230;
      dt260 = t - 260;
      dt296 = t - 296;
      ctw = dt260 * 5.050505e-4 * dt296 * cw230 - dt230 * 9.259259e-4
        * dt296 * cw260 + dt230 * 4.208754e-4 * dt260 * cw296;
      ctmpth = u / GSL_CONST_NUM_AVOGADRO / 1000 * p / P0 * ctw;
    } else
      ctmpth = 0;
    return ctmpth;
  }
```

5.13.2.7 double ctmh2o (double *nu*, double *p*, double *t*, double *q*, double *u*)

Compute water vapor continuum (optical depth).

Definition at line 1738 of file jurassic.c.

```
            {

  static double h2o296[2001] = { .17, .1695, .172, .168, .1687, .1624, .1606,
    .1508, .1447, .1344, .1214, .1133, .1009, .09217, .08297, .06989,
    .06513, .05469, .05056, .04417, .03779, .03484, .02994, .0272,
    .02325, .02063, .01818, .01592, .01405, .01251, .0108, .009647,
    .008424, .007519, .006555, .00588, .005136, .004511, .003989,
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    9.513e-14, 7.978e-14, 6.603e-14, 5.288e-14, 4.084e-14, 2.952e-14,
    2.157e-14, 1.593e-14, 1.199e-14, 9.267e-15, 7.365e-15, 6.004e-15,
    4.995e-15, 4.218e-15, 3.601e-15, 3.101e-15, 2.692e-15, 2.36e-15,
    2.094e-15, 1.891e-15, 1.755e-15, 1.699e-15, 1.755e-15, 1.987e-15,
    2.506e-15, 3.506e-15, 5.289e-15, 8.311e-15, 1.325e-14, 2.129e-14,
    3.237e-14, 4.595e-14, 6.441e-14, 8.433e-14, 1.074e-13, 1.383e-13,
    1.762e-13, 2.281e-13, 2.831e-13, 3.523e-13, 4.38e-13, 5.304e-13,
    6.29e-13, 7.142e-13, 8.032e-13, 8.934e-13, 9.888e-13, 1.109e-12,
    1.261e-12, 1.462e-12, 1.74e-12, 2.099e-12, 2.535e-12, 3.008e-12,
    3.462e-12, 3.856e-12, 4.098e-12, 4.239e-12, 4.234e-12, 4.132e-12,
    3.986e-12, 3.866e-12, 3.829e-12, 3.742e-12, 3.705e-12, 3.694e-12,
    3.765e-12, 3.849e-12, 3.929e-12, 4.056e-12, 4.092e-12, 4.047e-12,
    3.792e-12, 3.407e-12, 2.953e-12, 2.429e-12, 1.931e-12, 1.46e-12,
    1.099e-12, 8.199e-13, 6.077e-13, 4.449e-13, 3.359e-13, 2.524e-13,
    1.881e-13, 1.391e-13, 1.02e-13, 7.544e-14, 5.555e-14, 4.22e-14,
    3.321e-14, 2.686e-14, 2.212e-14, 1.78e-14, 1.369e-14, 1.094e-14,
    9.13e-15, 8.101e-15, 7.828e-15, 8.393e-15, 1.012e-14, 1.259e-14,
    1.538e-14, 1.961e-14, 2.619e-14, 3.679e-14, 5.049e-14, 6.917e-14,
    8.88e-14, 1.115e-13, 1.373e-13, 1.619e-13, 1.878e-13, 2.111e-13,
    2.33e-13, 2.503e-13, 2.613e-13, 2.743e-13, 2.826e-13, 2.976e-13,
    3.162e-13, 3.36e-13, 3.491e-13, 3.541e-13, 3.595e-13, 3.608e-13,
    3.709e-13, 3.869e-13, 4.12e-13, 4.366e-13, 4.504e-13, 4.379e-13,
    3.955e-13, 3.385e-13, 2.741e-13, 2.089e-13, 1.427e-13, 9.294e-14,
    5.775e-14, 3.565e-14, 2.21e-14, 1.398e-14, 9.194e-15, 6.363e-15,
    4.644e-15, 3.55e-15, 2.808e-15, 2.274e-15, 1.871e-15, 1.557e-15,
    1.308e-15, 1.108e-15, 9.488e-16, 8.222e-16, 7.238e-16, 6.506e-16,
    6.008e-16, 5.742e-16, 5.724e-16, 5.991e-16, 6.625e-16, 7.775e-16,
    9.734e-16, 1.306e-15, 1.88e-15, 2.879e-15, 4.616e-15, 7.579e-15,
    1.248e-14, 2.03e-14, 3.244e-14, 5.171e-14, 7.394e-14, 9.676e-14,
    1.199e-13, 1.467e-13, 1.737e-13, 2.02e-13, 2.425e-13, 3.016e-13,
    3.7e-13, 4.617e-13, 5.949e-13, 7.473e-13, 9.378e-13, 1.191e-12,
    1.481e-12, 1.813e-12, 2.232e-12, 2.722e-12, 3.254e-12, 3.845e-12,
    4.458e-12, 5.048e-12, 5.511e-12, 5.898e-12, 6.204e-12, 6.293e-12,
    6.386e-12, 6.467e-12, 6.507e-12, 6.466e-12, 6.443e-12, 6.598e-12,
    6.873e-12, 7.3e-12, 7.816e-12, 8.368e-12, 8.643e-12, 8.466e-12,
    7.871e-12, 6.853e-12, 5.714e-12, 4.482e-12, 3.392e-12, 2.613e-12,
    2.008e-12, 1.562e-12, 1.228e-12, 9.888e-13, 7.646e-13, 5.769e-13,
    4.368e-13, 3.324e-13, 2.508e-13, 1.916e-13
```

```
  };

  static double xfcrev[15] =
    { 1.003, 1.009, 1.015, 1.023, 1.029, 1.033, 1.037,
    1.039, 1.04, 1.046, 1.036, 1.027, 1.01, 1.002, 1.
  };

  double a1, a2, a3, dw, ew, dx, xw, xx, vf2, vf6, cw260, cw296,
    sfac, fscal, cwfrn, ctmpth, ctwfrn, ctwslf;

  int iw, jw, ix;

  /* Get H2O continuum absorption... */
  xw = nu / 10 + 1;
  if (xw >= 1 && xw < 2001) {
    iw = (int) xw;
    jw = iw + 1;
    dw = xw - iw;
    ew = 1 - dw;
    cw296 = ew * h2o296[iw - 1] + dw * h2o296[jw - 1];
    cw260 = ew * h2o260[iw - 1] + dw * h2o260[jw - 1];
    cwfrn = ew * h2ofrn[iw - 1] + dw * h2ofrn[jw - 1];
    if (nu <= 820 || nu >= 960) {
      sfac = 1;
    } else {
      xx = (nu - 820) / 10;
      ix = (int) xx;
      dx = xx - ix;
      sfac = (1 - dx) * xfcrev[ix] + dx * xfcrev[ix + 1];
    }
    ctwslf = sfac * cw296 * pow(cw260 / cw296, (296 - t) / (296 - 260));
    vf2 = gsl_pow_2(nu - 370);
    vf6 = gsl_pow_3(vf2);
    fscal = 36100 / (vf2 + vf6 * 1e-8 + 36100) * -.25 + 1;
    ctwfrn = cwfrn * fscal;
    a1 = nu * u * tanh(.7193876 / t * nu);
    a2 = 296 / t;
    a3 = p / P0 * (q * ctwslf + (1 - q) * ctwfrn) * 1e-20;
    ctmpth = a1 * a2 * a3;
  } else
    ctmpth = 0;
  return ctmpth;
}
```

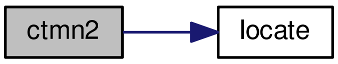
5.13.2.8 double ctmn2 (double *nu*, double *p*, double *t*)

Compute nitrogen continuum (absorption coefficient).

Definition at line 2792 of file jurassic.c.

```
             {

  static double ba[98] = { 0., 4.45e-8, 5.22e-8, 6.46e-8, 7.75e-8, 9.03e-8,
    1.06e-7, 1.21e-7, 1.37e-7, 1.57e-7, 1.75e-7, 2.01e-7, 2.3e-7,
    2.59e-7, 2.95e-7, 3.26e-7, 3.66e-7, 4.05e-7, 4.47e-7, 4.92e-7,
    5.34e-7, 5.84e-7, 6.24e-7, 6.67e-7, 7.14e-7, 7.26e-7, 7.54e-7,
    7.84e-7, 8.09e-7, 8.42e-7, 8.62e-7, 8.87e-7, 9.11e-7, 9.36e-7,
    9.76e-7, 1.03e-6, 1.11e-6, 1.23e-6, 1.39e-6, 1.61e-6, 1.76e-6,
    1.94e-6, 1.97e-6, 1.87e-6, 1.75e-6, 1.56e-6, 1.42e-6, 1.35e-6,
    1.32e-6, 1.29e-6, 1.29e-6, 1.29e-6, 1.3e-6, 1.32e-6, 1.33e-6,
    1.34e-6, 1.35e-6, 1.33e-6, 1.31e-6, 1.29e-6, 1.24e-6, 1.2e-6,
    1.16e-6, 1.1e-6, 1.04e-6, 9.96e-7, 9.38e-7, 8.63e-7, 7.98e-7,
    7.26e-7, 6.55e-7, 5.94e-7, 5.35e-7, 4.74e-7, 4.24e-7, 3.77e-7,
    3.33e-7, 2.96e-7, 2.63e-7, 2.34e-7, 2.08e-7, 1.85e-7, 1.67e-7,
    1.47e-7, 1.32e-7, 1.2e-7, 1.09e-7, 9.85e-8, 9.08e-8, 8.18e-8,
    7.56e-8, 6.85e-8, 6.14e-8, 5.83e-8, 5.77e-8, 5e-8, 4.32e-8, 0.
  };

  static double betaa[98] = { 802., 802., 761., 722., 679., 646., 609., 562.,
    511., 472., 436., 406., 377., 355., 338., 319., 299., 278., 255.,
    233., 208., 184., 149., 107., 66., 25., -13., -49., -82., -104.,
    -119., -130., -139., -144., -146., -146., -147., -148., -150.,
    -153., -160., -169., -181., -189., -195., -200., -205., -209.,
    -211., -210., -210., -209., -205., -199., -190., -180., -168.,
    -157., -143., -126., -108., -89., -63., -32., 1., 35., 65., 95.,
    121., 141., 152., 161., 164., 164., 161., 155., 148., 143., 137.,
    133., 131., 133., 139., 150., 165., 187., 213., 248., 284., 321.,
    372., 449., 514., 569., 609., 642., 673., 673.
  };

  static double nua[98] = { 2120., 2125., 2130., 2135., 2140., 2145., 2150.,
    2155., 2160., 2165., 2170., 2175., 2180., 2185., 2190., 2195.,
    2200., 2205., 2210., 2215., 2220., 2225., 2230., 2235., 2240.,
    2245., 2250., 2255., 2260., 2265., 2270., 2275., 2280., 2285.,
    2290., 2295., 2300., 2305., 2310., 2315., 2320., 2325., 2330.,
    2335., 2340., 2345., 2350., 2355., 2360., 2365., 2370., 2375.,
    2380., 2385., 2390., 2395., 2400., 2405., 2410., 2415., 2420.,
    2425., 2430., 2435., 2440., 2445., 2450., 2455., 2460., 2465.,
    2470., 2475., 2480., 2485., 2490., 2495., 2500., 2505., 2510.,
    2515., 2520., 2525., 2530., 2535., 2540., 2545., 2550., 2555.,
    2560., 2565., 2570., 2575., 2580., 2585., 2590., 2595., 2600., 2605.
  };

  double b, beta, q_n2 = 0.79, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[97])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 98, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t))
    * q_n2 * b * (q_n2 + (1 - q_n2) * (1.294 - 0.4545 * t / tr));
}
```

Here is the call graph for this function:



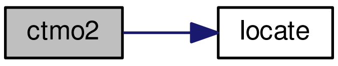
5.13.2.9 double ctmo2 (double *nu,* double *p,* double *t*)

Compute oxygen continuum (absorption coefficient).

Definition at line 2859 of file jurassic.c.

```
            {

  static double ba[90] = { 0., .061, .074, .084, .096, .12, .162, .208, .246,
    .285, .314, .38, .444, .5, .571, .673, .768, .853, .966, 1.097,
    1.214, 1.333, 1.466, 1.591, 1.693, 1.796, 1.922, 2.037, 2.154,
    2.264, 2.375, 2.508, 2.671, 2.847, 3.066, 3.417, 3.828, 4.204,
    4.453, 4.599, 4.528, 4.284, 3.955, 3.678, 3.477, 3.346, 3.29,
    3.251, 3.231, 3.226, 3.212, 3.192, 3.108, 3.033, 2.911, 2.798,
    2.646, 2.508, 2.322, 2.13, 1.928, 1.757, 1.588, 1.417, 1.253,
    1.109, .99, .888, .791, .678, .587, .524, .464, .403, .357, .32,
    .29, .267, .242, .215, .182, .16, .146, .128, .103, .087, .081,
    .071, .064, 0.
  };

  static double betaa[90] = { 467., 467., 400., 315., 379., 368., 475., 521.,
    531., 512., 442., 444., 430., 381., 335., 324., 296., 248., 215.,
    193., 158., 127., 101., 71., 31., -6., -26., -47., -63., -79.,
    -88., -88., -87., -90., -98., -99., -109., -134., -160., -167.,
    -164., -158., -153., -151., -156., -166., -168., -173., -170.,
    -161., -145., -126., -108., -84., -59., -29., 4., 41., 73., 97.,
    123., 159., 198., 220., 242., 256., 281., 311., 334., 319., 313.,
    321., 323., 310., 315., 320., 335., 361., 378., 373., 338., 319.,
    346., 322., 291., 290., 350., 371., 504., 504.
  };

  static double nua[90] = { 1360., 1365., 1370., 1375., 1380., 1385., 1390.,
    1395., 1400., 1405., 1410., 1415., 1420., 1425., 1430., 1435.,
    1440., 1445., 1450., 1455., 1460., 1465., 1470., 1475., 1480.,
    1485., 1490., 1495., 1500., 1505., 1510., 1515., 1520., 1525.,
    1530., 1535., 1540., 1545., 1550., 1555., 1560., 1565., 1570.,
    1575., 1580., 1585., 1590., 1595., 1600., 1605., 1610., 1615.,
    1620., 1625., 1630., 1635., 1640., 1645., 1650., 1655., 1660.,
    1665., 1670., 1675., 1680., 1685., 1690., 1695., 1700., 1705.,
    1710., 1715., 1720., 1725., 1730., 1735., 1740., 1745., 1750.,
    1755., 1760., 1765., 1770., 1775., 1780., 1785., 1790., 1795.,
    1800., 1805.
  };

  double b, beta, q_o2 = 0.21, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[89])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 90, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t)) * q_o2 * b;
}
```

Here is the call graph for this function:



5.13.2.10 void copy_atm (ctl_t * *ctl*, atm_t * *atm_dest*, atm_t * *atm_src*, int *init*)

Copy and initialize atmospheric data.

Definition at line 2920 of file jurassic.c.

```
               {

  int ig, ip, iw;

  size_t s;

  /* Data size... */
  s = (size_t) atm_src->np * sizeof(double);

  /* Copy data... */
  atm_dest->np = atm_src->np;
  memcpy(atm_dest->time, atm_src->time, s);
  memcpy(atm_dest->z, atm_src->z, s);
  memcpy(atm_dest->lon, atm_src->lon, s);
  memcpy(atm_dest->lat, atm_src->lat, s);
  memcpy(atm_dest->p, atm_src->p, s);
  memcpy(atm_dest->t, atm_src->t, s);
  for (ig = 0; ig < ctl->ng; ig++)
    memcpy(atm_dest->q[ig], atm_src->q[ig], s);
  for (iw = 0; iw < ctl->nw; iw++)
```

```
    memcpy(atm_dest->k[iw], atm_src->k[iw], s);

  /* Initialize... */
  if (init)
    for (ip = 0; ip < atm_dest->np; ip++) {
      atm_dest->p[ip] = 0;
      atm_dest->t[ip] = 0;
      for (ig = 0; ig < ctl->ng; ig++)
        atm_dest->q[ig][ip] = 0;
      for (iw = 0; iw < ctl->nw; iw++)
        atm_dest->k[iw][ip] = 0;
    }
}
```

5.13.2.11 void copy_obs (ctl_t * *ctl*, obs_t * *obs_dest*, obs_t * *obs_src*, int *init*)

Copy and initialize observation data.

Definition at line 2960 of file jurassic.c.

```
              {

  int id, ir;

  size_t s;

  /* Data size... */
  s = (size_t) obs_src->nr * sizeof(double);

  /* Copy data... */
  obs_dest->nr = obs_src->nr;
  memcpy(obs_dest->time, obs_src->time, s);
  memcpy(obs_dest->obsz, obs_src->obsz, s);
  memcpy(obs_dest->obslon, obs_src->obslon, s);
  memcpy(obs_dest->obslat, obs_src->obslat, s);
  memcpy(obs_dest->vpz, obs_src->vpz, s);
  memcpy(obs_dest->vplon, obs_src->vplon, s);
  memcpy(obs_dest->vplat, obs_src->vplat, s);
  memcpy(obs_dest->tpz, obs_src->tpz, s);
  memcpy(obs_dest->tplon, obs_src->tplon, s);
  memcpy(obs_dest->tplat, obs_src->tplat, s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->rad[id], obs_src->rad[id], s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->tau[id], obs_src->tau[id], s);

  /* Initialize... */
  if (init)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs_dest->nr; ir++)
        if (gsl_finite(obs_dest->rad[id][ir])) {
          obs_dest->rad[id][ir] = 0;
          obs_dest->tau[id][ir] = 0;
        }
}
```

5.13.2.12 int find_emitter (ctl_t * *ctl*, const char * *emitter*)

Find index of an emitter.

Definition at line 3002 of file jurassic.c.

```
                           {

  int ig;

  for (ig = 0; ig < ctl->ng; ig++)
    if (strcasecmp(ctl->emitter[ig], emitter) == 0)
      return ig;

  return -1;
}
```

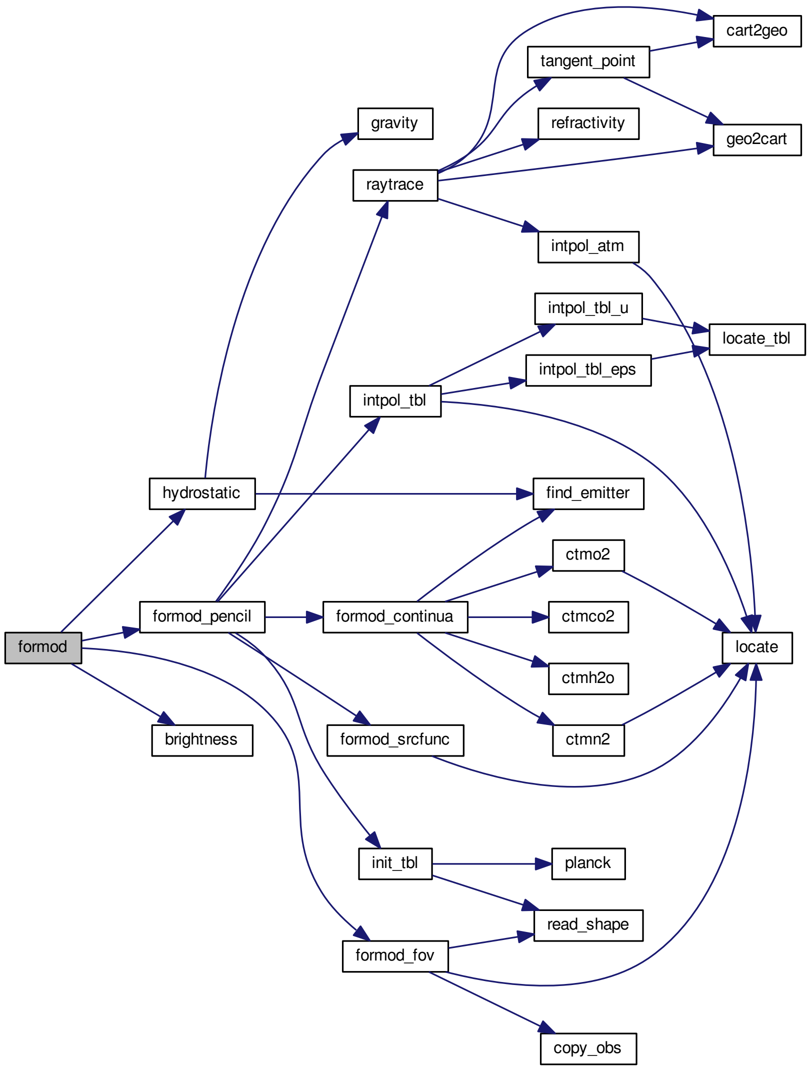
5.13.2.13 void formod (ctl_t * *ctl,* atm_t * *atm,* obs_t * *obs*)

Determine ray paths and compute radiative transfer.

Definition at line 3017 of file jurassic.c.

```
                {

  int id, ir, *mask;

  /* Allocate... */
  ALLOC(mask, int,
        ND * NR);

  /* Save observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      mask[id * NR + ir] = !gsl_finite(obs->rad[id][ir]);

  /* Hydrostatic equilibrium... */
  hydrostatic(ctl, atm);

  /* Claculate pencil beams... */
  for (ir = 0; ir < obs->nr; ir++)
    formod_pencil(ctl, atm, obs, ir);

  /* Apply field-of-view convolution... */
  formod_fov(ctl, obs);

  /* Convert radiance to brightness temperature... */
  if (ctl->write_bbt)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs->nr; ir++)
        obs->rad[id][ir] = brightness(obs->rad[id][ir], ctl->nu[id]);

  /* Apply observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      if (mask[id * NR + ir])
        obs->rad[id][ir] = GSL_NAN;

  /* Free... */
  free(mask);
}
```

Here is the call graph for this function:



5.13.2.14 void formod_continua (ctl_t ∗ *ctl*, los_t ∗ *los*, int *ip*, double ∗ *beta*)

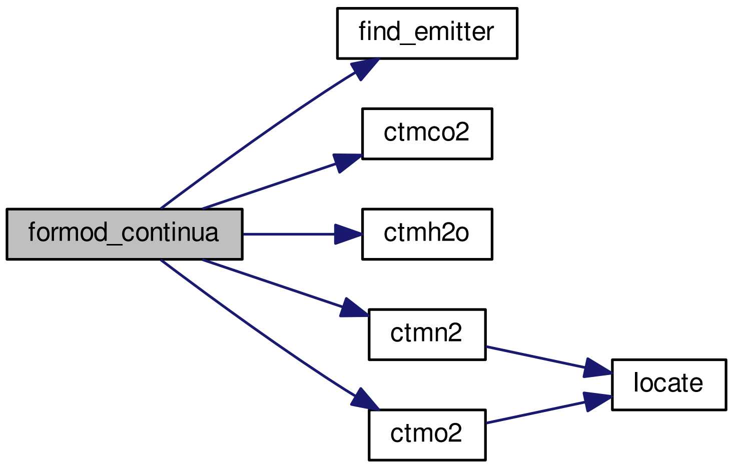
Compute absorption coefficient of continua.

Definition at line 3061 of file jurassic.c.

```
                  {

  static int ig_co2 = -999, ig_h2o = -999;

  int id;

  /* Extinction... */
  for (id = 0; id < ctl->nd; id++)
    beta[id] = los->k[ctl->window[id]][ip];

  /* CO2 continuum... */
  if (ctl->ctm_co2) {
    if (ig_co2 == -999)
```

```
      ig_co2 = find_emitter(ctl, "CO2");
    if (ig_co2 >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmco2(ctl->nu[id], los->p[ip], los->t[ip],
                           los->u[ig_co2][ip]) / los->ds[ip];
  }

  /* H2O continuum... */
  if (ctl->ctm_h2o) {
    if (ig_h2o == -999)
      ig_h2o = find_emitter(ctl, "H2O");
    if (ig_h2o >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmh2o(ctl->nu[id], los->p[ip], los->t[ip],
                           los->q[ig_h2o][ip],
                           los->u[ig_h2o][ip]) / los->ds[ip];
  }

  /* N2 continuum... */
  if (ctl->ctm_n2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmn2(ctl->nu[id], los->p[ip], los->t[ip]);

  /* O2 continuum... */
  if (ctl->ctm_o2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmo2(ctl->nu[id], los->p[ip], los->t[ip]);
}
```

Here is the call graph for this function:



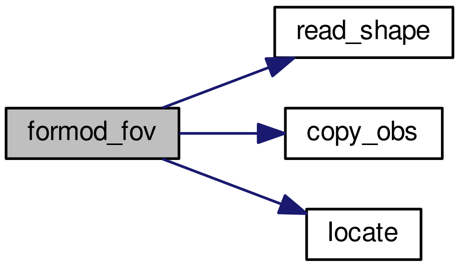
5.13.2.15 void formod_fov (ctl_t * *ctl*, obs_t * *obs*)

Apply field of view convolution.

Definition at line 3109 of file jurassic.c.

```
                {

  static double dz[NSHAPE], w[NSHAPE];

  static int init = 0, n;

  obs_t *obs2;

  double rad[ND][NR], tau[ND][NR], wsum, z[NR], zfov;

  int i, id, idx, ir, ir2, nz;

  /* Do not take into account FOV... */
  if (ctl->fov[0] == '-')
    return;

  /* Initialize FOV data... */
  if (!init) {
    init = 1;
    read_shape(ctl->fov, dz, w, &n);
  }

  /* Allocate... */
  ALLOC(obs2, obs_t, 1);

  /* Copy observation data... */
  copy_obs(ctl, obs2, obs, 0);

  /* Loop over ray paths... */
  for (ir = 0; ir < obs->nr; ir++) {

    /* Get radiance and transmittance profiles... */
    nz = 0;
    for (ir2 = GSL_MAX(ir - NFOV, 0); ir2 < GSL_MIN(ir + 1 + NFOV, obs->nr);
         ir2++)
      if (obs->time[ir2] == obs->time[ir]) {
        z[nz] = obs2->vpz[ir2];
        for (id = 0; id < ctl->nd; id++) {
          rad[id][nz] = obs2->rad[id][ir2];
          tau[id][nz] = obs2->tau[id][ir2];
        }
        nz++;
      }
    if (nz < 2)
      ERRMSG("Cannot apply FOV convolution!");

    /* Convolute profiles with FOV... */
    wsum = 0;
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] = 0;
      obs->tau[id][ir] = 0;
    }
    for (i = 0; i < n; i++) {
      zfov = obs->vpz[ir] + dz[i];
      idx = locate(z, nz, zfov);
      for (id = 0; id < ctl->nd; id++) {
        obs->rad[id][ir] += w[i]
          * LIN(z[idx], rad[id][idx], z[idx + 1], rad[id][idx + 1], zfov);
        obs->tau[id][ir] += w[i]
          * LIN(z[idx], tau[id][idx], z[idx + 1], tau[id][idx + 1], zfov);
      }
      wsum += w[i];
    }
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] /= wsum;
      obs->tau[id][ir] /= wsum;
    }
  }

  /* Free... */
  free(obs2);
}
```

Here is the call graph for this function:



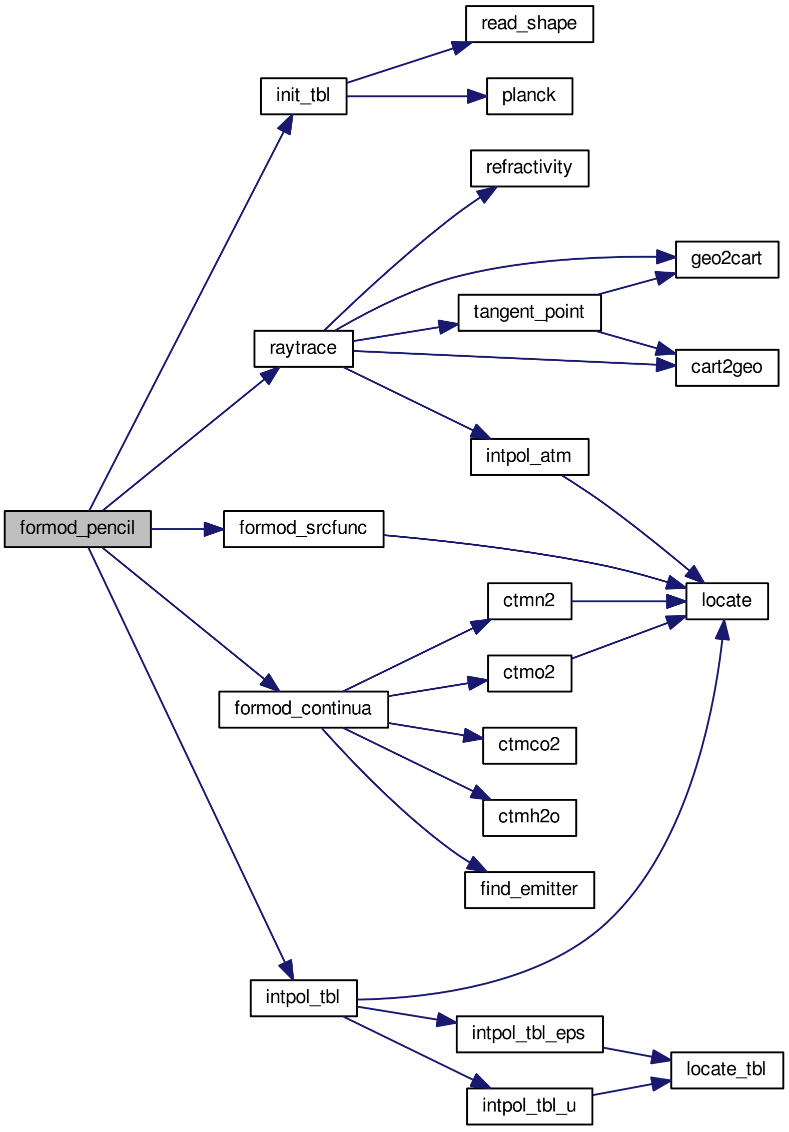
5.13.2.16 void formod_pencil (ctl_t * *ctl*, atm_t * *atm*, obs_t * *obs*, int *ir*)

Compute radiative transfer for a pencil beam.

Definition at line 3186 of file jurassic.c.

```
        {

  static tbl_t *tbl;

  static int init = 0;

  los_t *los;

  double beta_ctm[ND], eps, src_planck[ND], tau_path[NG][ND], tau_gas[ND];

  int id, ip;

  /* Initialize look-up tables... */
  if (!init) {
    init = 1;
    ALLOC(tbl, tbl_t, 1);
    init_tbl(ctl, tbl);
  }

  /* Allocate... */
  ALLOC(los, los_t, 1);

  /* Initialize... */
  for (id = 0; id < ctl->nd; id++) {
    obs->rad[id][ir] = 0;
    obs->tau[id][ir] = 1;
  }

  /* Raytracing... */
  raytrace(ctl, atm, obs, los, ir);

  /* Loop over LOS points... */
  for (ip = 0; ip < los->np; ip++) {

    /* Get trace gas transmittance... */
    intpol_tbl(ctl, tbl, los, ip, tau_path, tau_gas);

    /* Get continuum absorption... */
    formod_continua(ctl, los, ip, beta_ctm);

    /* Compute Planck function... */
    formod_srcfunc(ctl, tbl, los->t[ip], src_planck);

    /* Loop over channels... */
    for (id = 0; id < ctl->nd; id++)
      if (tau_gas[id] > 0) {

        /* Get segment emissivity... */
        eps = 1 - tau_gas[id] * exp(-beta_ctm[id] * los->ds[ip]);

        /* Compute radiance... */
        obs->rad[id][ir] += src_planck[id] * eps * obs->tau[id][ir];

        /* Compute path transmittance... */
        obs->tau[id][ir] *= (1 - eps);
      }
  }

  /* Add surface... */
  if (los->tsurf > 0) {
    formod_srcfunc(ctl, tbl, los->tsurf, src_planck);
    for (id = 0; id < ctl->nd; id++)
      obs->rad[id][ir] += src_planck[id] * obs->tau[id][ir];
  }

  /* Free... */
  free(los);
}
```

Here is the call graph for this function:



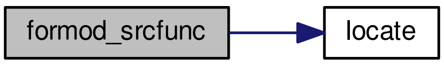
5.13.2.17 void formod_srcfunc (ctl_t * *ctl*, tbl_t * *tbl*, double *t*, double * *src*)

Compute Planck source function.

Definition at line 3261 of file jurassic.c.

```
                 {

  int id, it;

  /* Determine index in temperature array... */
  it = locate(tbl->st, TBLNS, t);

  /* Interpolate Planck function value... */
  for (id = 0; id < ctl->nd; id++)
    src[id] = LIN(tbl->st[it], tbl->sr[id][it],
                  tbl->st[it + 1], tbl->sr[id][it + 1], t);
}
```

Here is the call graph for this function:



5.13.2.18 void geo2cart (double *z*, double *lon*, double *lat*, double * *x*)

Convert geolocation to Cartesian coordinates.

Definition at line 3280 of file jurassic.c.

```
               {

  double radius;

  radius = z + RE;
  x[0] = radius * cos(lat / 180 * M_PI) * cos(lon / 180 * M_PI);
  x[1] = radius * cos(lat / 180 * M_PI) * sin(lon / 180 * M_PI);
  x[2] = radius * sin(lat / 180 * M_PI);
}
```

5.13.2.19 double gravity (double *z*, double *lat*)

Determine gravity of Earth.

Definition at line 3296 of file jurassic.c.

```
                {

  /* Compute gravity according to 1967 Geodetic Reference System... */
  return 9.780318 * (1 + 0.0053024 * gsl_pow_2(sin(lat / 180 * M_PI))
                     - 0.0000058 * gsl_pow_2(sin(2 * lat / 180 * M_PI))) -
    3.086e-3 * z;
}
```

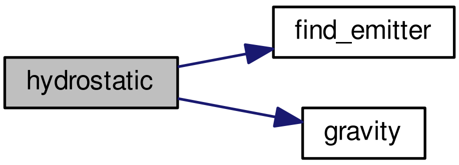
5.13.2.20 void hydrostatic (ctl_t * ctl, atm_t * atm)

Set hydrostatic equilibrium.

Definition at line 3308 of file jurassic.c.

```
                {

  static int ig_h2o = -999;

  double dzmin = 1e99, e = 0, mean, mmair = 28.96456e-3, mmh2o =
    18.0153e-3, z;

  int i, ip, ipref = 0, ipts = 20;

  /* Check reference height... */
  if (ctl->hydz < 0)
    return;

  /* Determine emitter index of H2O... */
  if (ig_h2o == -999)
    ig_h2o = find_emitter(ctl, "H2O");

  /* Find air parcel next to reference height... */
  for (ip = 0; ip < atm->np; ip++)
    if (fabs(atm->z[ip] - ctl->hydz) < dzmin) {
      dzmin = fabs(atm->z[ip] - ctl->hydz);
      ipref = ip;
    }

  /* Upper part of profile... */
  for (ip = ipref + 1; ip < atm->np; ip++) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip - 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip - 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip - 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip - 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip - 1]));
  }

  /* Lower part of profile... */
  for (ip = ipref - 1; ip >= 0; ip--) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip + 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip + 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip + 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip + 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip + 1]));
  }
}
```

Here is the call graph for this function:



5.13.2.21 void idx2name (ctl_t * *ctl*, int *idx*, char * *quantity*)

Determine name of state vector quantity for given index.

Definition at line 3373 of file jurassic.c.

```
                    {

  int ig, iw;

  if (idx == IDXP)
    sprintf(quantity, "PRESSURE");

  if (idx == IDXT)
    sprintf(quantity, "TEMPERATURE");

  for (ig = 0; ig < ctl->ng; ig++)
    if (idx == IDXQ(ig))
      sprintf(quantity, "%s", ctl->emitter[ig]);

  for (iw = 0; iw < ctl->nw; iw++)
    if (idx == IDXK(iw))
      sprintf(quantity, "EXTINCT_WINDOW%d", iw);
}
```

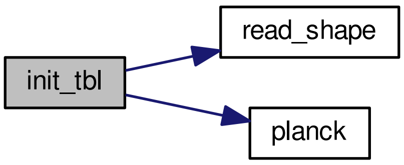
5.13.2.22 void init_tbl (ctl_t * *ctl*, tbl_t * *tbl*)

Initialize look-up tables.

Definition at line 3397 of file jurassic.c.

```
                {

  FILE *in;

  char filename[LEN], line[LEN];

  double eps, eps_old, press, press_old, temp, temp_old, u, u_old,
    f[NSHAPE], fsum, nu[NSHAPE];

  int i, id, ig, ip, it, n;

  /* Loop over trace gases and channels... */
  for (ig = 0; ig < ctl->ng; ig++)
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(in,filename,line,eps,eps_old,press,
press_old,temp,temp_old,u,u_old,id,ip,it)
    for (id = 0; id < ctl->nd; id++) {

      /* Initialize... */
      tbl->np[ig][id] = -1;
      eps_old = -999;
      press_old = -999;
      temp_old = -999;
      u_old = -999;

      /* Try to open file... */
      sprintf(filename, "%s_%.4f_%s.tab",
              ctl->tblbase, ctl->nu[id], ctl->emitter[ig]);
      if (!(in = fopen(filename, "r"))) {
        printf("Missing emissivity table: %s\n", filename);
        continue;
      }
      printf("Read emissivity table: %s\n", filename);

      /* Read data... */
      while (fgets(line, LEN, in)) {

        /* Parse line... */
        if (sscanf(line, "%lg %lg %lg %lg", &press, &temp, &u, &eps) != 4)
          continue;

        /* Determine pressure index... */
        if (press != press_old) {
          press_old = press;
          if ((++tbl->np[ig][id]) >= TBLNP)
            ERRMSG("Too many pressure levels!");
          tbl->nt[ig][id][tbl->np[ig][id]] = -1;
        }

        /* Determine temperature index... */
        if (temp != temp_old) {
          temp_old = temp;
          if ((++tbl->nt[ig][id][tbl->np[ig][id]]) >= TBLNT)
            ERRMSG("Too many temperatures!");
          tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] = -1;
        }

        /* Determine column density index... */
        if ((eps > eps_old && u > u_old) || tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] < 0) {
          eps_old = eps;
          u_old = u;
          if ((++tbl->nu[ig][id][tbl->np[ig][id]]
               [tbl->nt[ig][id][tbl->np[ig][id]]]) >= TBLNU) {
            tbl->nu[ig][id][tbl->np[ig][id]]
              [tbl->nt[ig][id][tbl->np[ig][id]]]--;
            continue;
          }
        }

        /* Store data... */
        tbl->p[ig][id][tbl->np[ig][id]] = press;
        tbl->t[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          = temp;
        tbl->u[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) u;
        tbl->eps[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) eps;
      }

      /* Increment counters... */
      tbl->np[ig][id]++;
      for (ip = 0; ip < tbl->np[ig][id]; ip++) {
        tbl->nt[ig][id][ip]++;
        for (it = 0; it < tbl->nt[ig][id][ip]; it++)
          tbl->nu[ig][id][ip][it]++;
      }

      /* Close file... */
      fclose(in);
    }

  /* Write info... */
  printf("Initialize source function table...\n");

  /* Loop over channels... */
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(filename,it,i,n,f,fsum,nu)
  for (id = 0; id < ctl->nd; id++) {

    /* Read filter function... */
    sprintf(filename, "%s_%.4f.filt", ctl->tblbase, ctl->nu[id]);
    read_shape(filename, nu, f, &n);

    /* Compute source function table... */
    for (it = 0; it < TBLNS; it++) {

      /* Set temperature... */
      tbl->st[it] = LIN(0.0, TMIN, TBLNS - 1.0, TMAX, (double) it);

      /* Integrate Planck function... */
      fsum = 0;
      tbl->sr[id][it] = 0;
      for (i = 0; i < n; i++) {
        fsum += f[i];
        tbl->sr[id][it] += f[i] * planck(tbl->st[it], nu[i]);
      }
      tbl->sr[id][it] /= fsum;
    }
  }
}
```

Here is the call graph for this function:



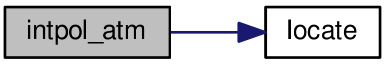
5.13.2.23 void intpol_atm (ctl_t * *ctl,* atm_t * *atm,* double *z,* double * *p,* double * *t,* double * *q,* double * *k*)

Interpolate atmospheric data.

Definition at line 3523 of file jurassic.c.

```
               {

  int ig, ip, iw;

  /* Get array index... */
  ip = locate(atm->z, atm->np, z);

  /* Interpolate... */
  *p = EXP(atm->z[ip], atm->p[ip], atm->z[ip + 1], atm->p[ip + 1], z);
  *t = LIN(atm->z[ip], atm->t[ip], atm->z[ip + 1], atm->t[ip + 1], z);
  for (ig = 0; ig < ctl->ng; ig++)
    q[ig] =
      LIN(atm->z[ip], atm->q[ig][ip], atm->z[ip + 1], atm->q[ig][ip + 1], z);
  for (iw = 0; iw < ctl->nw; iw++)
    k[iw] =
      LIN(atm->z[ip], atm->k[iw][ip], atm->z[ip + 1], atm->k[iw][ip + 1], z);
}
```

Here is the call graph for this function:



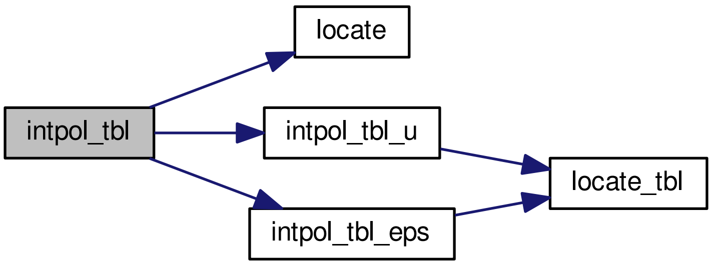
5.13.2.24 void intpol_tbl (ctl_t * *ctl*, tbl_t * *tbl*, los_t * *los*, int *ip*, double *tau_path[NG][ND]*, double *tau_seg[ND]*)

Get transmittance from look-up tables.

Definition at line 3550 of file jurassic.c.

```
                        {

  double eps, eps00, eps01, eps10, eps11, u;

  int id, ig, ipr, it0, it1;

  /* Initialize... */
  if (ip <= 0)
    for (ig = 0; ig < ctl->ng; ig++)
      for (id = 0; id < ctl->nd; id++)
        tau_path[ig][id] = 1;

  /* Loop over channels... */
  for (id = 0; id < ctl->nd; id++) {

    /* Initialize... */
    tau_seg[id] = 1;

    /* Loop over emitters.... */
    for (ig = 0; ig < ctl->ng; ig++) {

      /* Check size of table (pressure)... */
      if (tbl->np[ig][id] < 2)
        eps = 0;

      /* Check transmittance... */
      else if (tau_path[ig][id] < 1e-9)
        eps = 1;

      /* Interpolate... */
      else {

        /* Determine pressure and temperature indices... */
        ipr = locate(tbl->p[ig][id], tbl->np[ig][id], los->p[ip]);
        it0 = locate(tbl->t[ig][id][ipr], tbl->nt[ig][id][ipr], los->t[ip]);
        it1 =
          locate(tbl->t[ig][id][ipr + 1], tbl->nt[ig][id][ipr + 1],
                 los->t[ip]);

        /* Check size of table (temperature and column density)... */
        if (tbl->nt[ig][id][ipr] < 2 || tbl->nt[ig][id][ipr + 1] < 2
            || tbl->nu[ig][id][ipr][it0] < 2
            || tbl->nu[ig][id][ipr][it0 + 1] < 2
            || tbl->nu[ig][id][ipr + 1][it1] < 2
            || tbl->nu[ig][id][ipr + 1][it1 + 1] < 2)
          eps = 0;

        else {

          /* Get emissivities of extended path... */
          u = intpol_tbl_u(tbl, ig, id, ipr, it0, 1 - tau_path[ig][id]);
          eps00 = intpol_tbl_eps(tbl, ig, id, ipr, it0, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr, it0 + 1, 1 - tau_path[ig][id]);
          eps01 =
            intpol_tbl_eps(tbl, ig, id, ipr, it0 + 1, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr + 1, it1, 1 - tau_path[ig][id]);
          eps10 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1, u + los->u[ig][ip]);

          u =
            intpol_tbl_u(tbl, ig, id, ipr + 1, it1 + 1, 1 - tau_path[ig][id]);
          eps11 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1 + 1, u + los->
      u[ig][ip]);

          /* Interpolate with respect to temperature... */
          eps00 = LIN(tbl->t[ig][id][ipr][it0], eps00,
                      tbl->t[ig][id][ipr][it0 + 1], eps01, los->t[ip]);
          eps11 = LIN(tbl->t[ig][id][ipr + 1][it1], eps10,
                      tbl->t[ig][id][ipr + 1][it1 + 1], eps11, los->t[ip]);

          /* Interpolate with respect to pressure... */
          eps00 = LIN(tbl->p[ig][id][ipr], eps00,
                      tbl->p[ig][id][ipr + 1], eps11, los->p[ip]);

          /* Check emssivity range... */
          eps00 = GSL_MAX(GSL_MIN(eps00, 1), 0);

          /* Determine segment emissivity... */
          eps = 1 - (1 - eps00) / tau_path[ig][id];
        }
      }

      /* Get transmittance of extended path... */
      tau_path[ig][id] *= (1 - eps);

      /* Get segment transmittance... */
      tau_seg[id] *= (1 - eps);
    }
  }
}
```

Here is the call graph for this function:



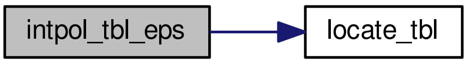
5.13.2.25 double intpol_tbl_eps (tbl_t * *tbl*, int *ig*, int *id*, int *ip*, int *it*, double *u*)

Interpolate emissivity from look-up tables.

Definition at line 3651 of file jurassic.c.

```
                  {

  int idx;

  /* Lower boundary... */
  if (u < tbl->u[ig][id][ip][it][0])
    return LIN(0, 0, tbl->u[ig][id][ip][it][0], tbl->eps[ig][id][ip][it][0],
               u);

  /* Upper boundary... */
  else if (u > tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1e30, 1, u);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->u[ig][id][ip][it], tbl->nu[ig][id][ip][it], u);

    /* Interpolate... */
    return
      LIN(tbl->u[ig][id][ip][it][idx], tbl->eps[ig][id][ip][it][idx],
          tbl->u[ig][id][ip][it][idx + 1], tbl->eps[ig][id][ip][it][idx + 1],
          u);
  }
}
```

Here is the call graph for this function:



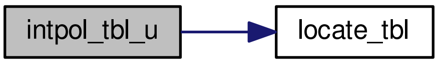
5.13.2.26 double intpol_tbl_u (**tbl_t** ∗ *tbl,* int *ig,* int *id,* int *ip,* int *it,* double *eps*)

Interpolate column density from look-up tables.

Definition at line 3688 of file jurassic.c.

```
                 {

  int idx;

  /* Lower boundary... */
  if (eps < tbl->eps[ig][id][ip][it][0])
    return LIN(0, 0, tbl->eps[ig][id][ip][it][0], tbl->u[ig][id][ip][it][0],
               eps);

  /* Upper boundary... */
  else if (eps > tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1, 1e30, eps);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->eps[ig][id][ip][it], tbl->nu[ig][id][ip][it], eps);

    /* Interpolate... */
    return
      LIN(tbl->eps[ig][id][ip][it][idx], tbl->u[ig][id][ip][it][idx],
          tbl->eps[ig][id][ip][it][idx + 1], tbl->u[ig][id][ip][it][idx + 1],
          eps);
  }
}
```

Here is the call graph for this function:



5.13.2.27 void jsec2time (double *jsec,* int ∗ *year,* int ∗ *mon,* int ∗ *day,* int ∗ *hour,* int ∗ *min,* int ∗ *sec,* double ∗ *remain*)

Convert seconds to date.

Definition at line 3725 of file jurassic.c.

```
                   {

  struct tm t0, *t1;

  time_t jsec0;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}
```

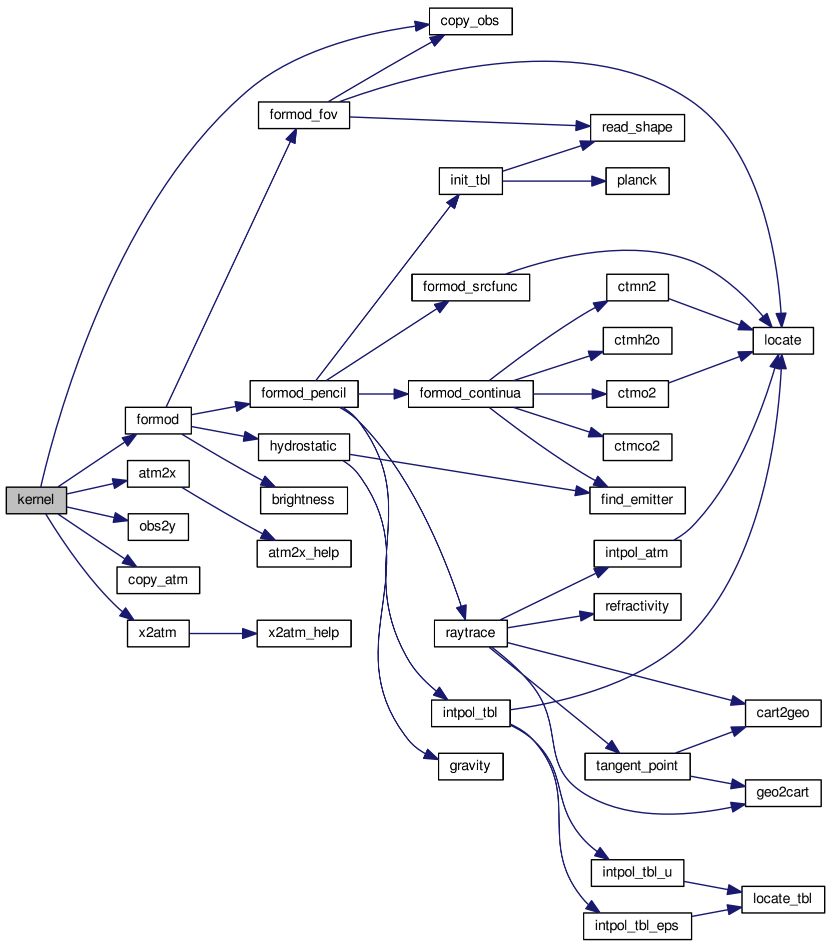
5.13.2.28 void kernel (ctl_t ∗ *ctl,* atm_t ∗ *atm,* obs_t ∗ *obs,* gsl_matrix ∗ *k*)

Compute Jacobians.

Definition at line 3760 of file jurassic.c.

```
                   {

  atm_t *atm1;
  obs_t *obs1;

  gsl_vector *x0, *x1, *yy0, *yy1;

  int *iqa, j;

  double h;

  size_t i, n, m;

  /* Get sizes... */
  m = k->size1;
  n = k->size2;

  /* Allocate... */
  x0 = gsl_vector_alloc(n);
  yy0 = gsl_vector_alloc(m);
  ALLOC(iqa, int,
        N);

  /* Compute radiance for undisturbed atmospheric data... */
  formod(ctl, atm, obs);

  /* Compose vectors... */
  atm2x(ctl, atm, x0, iqa, NULL);
  obs2y(ctl, obs, yy0, NULL, NULL);

  /* Initialize kernel matrix... */
  gsl_matrix_set_zero(k);

  /* Loop over state vector elements... */
#pragma omp parallel for default(none) shared(ctl,atm,obs,k,x0,yy0,n,m,iqa) private(i, j, h, x1, yy1, atm1,
 obs1)
  for (j = 0; j < (int) n; j++) {

    /* Allocate... */
    x1 = gsl_vector_alloc(n);
    yy1 = gsl_vector_alloc(m);
    ALLOC(atm1, atm_t, 1);
    ALLOC(obs1, obs_t, 1);

    /* Set perturbation size... */
    if (iqa[j] == IDXP)
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-7);
    else if (iqa[j] == IDXT)
      h = 1;
    else if (iqa[j] >= IDXQ(0) && iqa[j] < IDXQ(ctl->ng))
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-15);
    else if (iqa[j] >= IDXK(0) && iqa[j] < IDXK(ctl->nw))
      h = 1e-4;
    else
      ERRMSG("Cannot set perturbation size!");

    /* Disturb state vector element... */
    gsl_vector_memcpy(x1, x0);
    gsl_vector_set(x1, (size_t) j, gsl_vector_get(x1, (size_t) j) + h);
    copy_atm(ctl, atm1, atm, 0);
    copy_obs(ctl, obs1, obs, 0);
    x2atm(ctl, x1, atm1);

    /* Compute radiance for disturbed atmospheric data... */
    formod(ctl, atm1, obs1);

    /* Compose measurement vector for disturbed radiance data... */
    obs2y(ctl, obs1, yy1, NULL, NULL);

    /* Compute derivatives... */
    for (i = 0; i < m; i++)
      gsl_matrix_set(k, i, (size_t) j,
                     (gsl_vector_get(yy1, i) - gsl_vector_get(yy0, i)) / h);

    /* Free... */
    gsl_vector_free(x1);
    gsl_vector_free(yy1);
    free(atm1);
    free(obs1);
  }

  /* Free... */
  gsl_vector_free(x0);
  gsl_vector_free(yy0);
  free(iqa);
}
```

Here is the call graph for this function:



5.13.2.29 int locate (double ∗ *xx,* int *n,* double *x*)

Find array index.

Definition at line 3852 of file jurassic.c.

```
            {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}
```

5.13.2.30 int locate_tbl (float ∗ *xx,* int *n,* double *x*)

Find array index in float array.

Definition at line 3884 of file jurassic.c.

```
                {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  while (ihi > ilo + 1) {
    i = (ihi + ilo) >> 1;
    if (xx[i] > x)
      ihi = i;
    else
      ilo = i;
  }

  return ilo;
}
```

5.13.2.31 size_t obs2y (ctl_t ∗ *ctl,* obs_t ∗ *obs,* gsl_vector ∗ *y,* int ∗ *ida,* int ∗ *ira*)

Compose measurement vector.

Definition at line 3908 of file jurassic.c.

```
                {

  int id, ir;

  size_t m = 0;

  /* Determine measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        if (y != NULL)
          gsl_vector_set(y, m, obs->rad[id][ir]);
        if (ida != NULL)
          ida[m] = id;
        if (ira != NULL)
          ira[m] = ir;
        m++;
      }

  return m;
}
```

5.13.2.32 double planck (double *t,* double *nu*)

Compute Planck function.

Definition at line 3937 of file jurassic.c.

```
                 {

  return C1 * gsl_pow_3(nu) / gsl_expm1(C2 * nu / t);
}
```

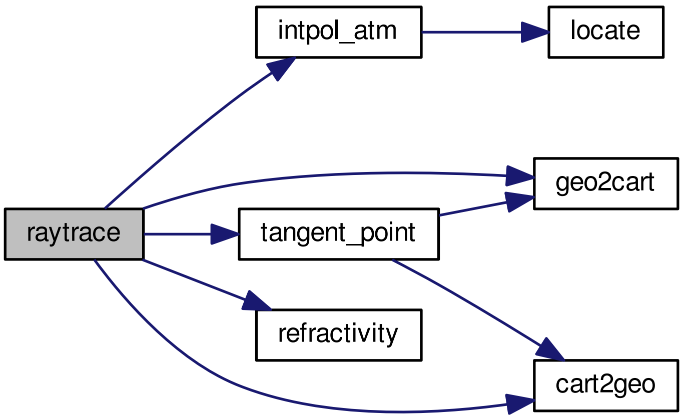
5.13.2.33 void raytrace (ctl_t * *ctl*, atm_t * *atm*, obs_t * *obs*, los_t * *los*, int *ir*)

Do ray-tracing to determine LOS.

Definition at line 3946 of file jurassic.c.

```
        {

  double cosa, d, dmax, dmin = 0, ds, ex0[3], ex1[3], frac, h = 0.02, k[NW],
    lat, lon, n, naux, ng[3], norm, p, q[NG], t, x[3], xh[3],
    xobs[3], xvp[3], z = 1e99, zmax, zmin, zrefrac = 60;

  int i, ig, ip, iw, stop = 0;

  /* Initialize... */
  los->np = 0;
  los->tsurf = -999;
  obs->tpz[ir] = obs->vpz[ir];
  obs->tplon[ir] = obs->vplon[ir];
  obs->tplat[ir] = obs->vplat[ir];

  /* Get altitude range of atmospheric data... */
  gsl_stats_minmax(&zmin, &zmax, atm->z, 1, (size_t) atm->np);

  /* Check observer altitude... */
  if (obs->obsz[ir] < zmin)
    ERRMSG("Observer below surface!");

  /* Check view point altitude... */
  if (obs->vpz[ir] > zmax)
    return;

  /* Determine Cartesian coordinates for observer and view point... */
  geo2cart(obs->obsz[ir], obs->obslon[ir], obs->obslat[ir], xobs);
  geo2cart(obs->vpz[ir], obs->vplon[ir], obs->vplat[ir], xvp);

  /* Determine initial tangent vector... */
  for (i = 0; i < 3; i++)
    ex0[i] = xvp[i] - xobs[i];
  norm = NORM(ex0);
  for (i = 0; i < 3; i++)
    ex0[i] /= norm;

  /* Observer within atmosphere... */
  for (i = 0; i < 3; i++)
    x[i] = xobs[i];

  /* Observer above atmosphere (search entry point)... */
  if (obs->obsz[ir] > zmax) {
    dmax = norm;
    while (fabs(dmin - dmax) > 0.001) {
      d = (dmax + dmin) / 2;
      for (i = 0; i < 3; i++)
        x[i] = xobs[i] + d * ex0[i];
      cart2geo(x, &z, &lon, &lat);
      if (z <= zmax && z > zmax - 0.001)
        break;
      if (z < zmax - 0.0005)
        dmax = d;
      else
        dmin = d;
    }
  }

  /* Ray-tracing... */
  while (1) {

    /* Set step length... */
    ds = ctl->rayds;
    if (ctl->raydz > 0) {
      norm = NORM(x);
      for (i = 0; i < 3; i++)
        xh[i] = x[i] / norm;
      cosa = fabs(DOTP(ex0, xh));
      if (cosa != 0)
        ds = GSL_MIN(ctl->rayds, ctl->raydz / cosa);
    }

    /* Determine geolocation... */
    cart2geo(x, &z, &lon, &lat);

    /* Check if LOS hits the ground or has left atmosphere... */
    if (z < zmin || z > zmax) {
      stop = (z < zmin ? 2 : 1);
      frac =
        ((z <
          zmin ? zmin : zmax) - los->z[los->np - 1]) / (z - los->z[los->np -
                                                                    1]);
      geo2cart(los->z[los->np - 1], los->lon[los->np - 1],
               los->lat[los->np - 1], xh);
      for (i = 0; i < 3; i++)
        x[i] = xh[i] + frac * (x[i] - xh[i]);
      cart2geo(x, &z, &lon, &lat);
      los->ds[los->np - 1] = ds * frac;
      ds = 0;
    }

    /* Interpolate atmospheric data... */
    intpol_atm(ctl, atm, z, &p, &t, q, k);

    /* Save data... */
    los->lon[los->np] = lon;
    los->lat[los->np] = lat;
    los->z[los->np] = z;
    los->p[los->np] = p;
    los->t[los->np] = t;
    for (ig = 0; ig < ctl->ng; ig++)
      los->q[ig][los->np] = q[ig];
    for (iw = 0; iw < ctl->nw; iw++)
      los->k[iw][los->np] = k[iw];
    los->ds[los->np] = ds;

    /* Increment and check number of LOS points... */
    if ((++los->np) > NLOS)
      ERRMSG("Too many LOS points!");

    /* Check stop flag... */
    if (stop) {
      los->tsurf = (stop == 2 ? t : -999);
      break;
    }

    /* Determine refractivity... */
    if (ctl->refrac && z <= zrefrac)
      n = 1 + refractivity(p, t);
    else
      n = 1;

    /* Construct new tangent vector (first term)... */
    for (i = 0; i < 3; i++)
      ex1[i] = ex0[i] * n;

    /* Compute gradient of refractivity... */
    if (ctl->refrac && z <= zrefrac) {
      for (i = 0; i < 3; i++)
        xh[i] = x[i] + 0.5 * ds * ex0[i];
      cart2geo(xh, &z, &lon, &lat);
      intpol_atm(ctl, atm, z, &p, &t, q, k);
      n = refractivity(p, t);
      for (i = 0; i < 3; i++) {
        xh[i] += h;
        cart2geo(xh, &z, &lon, &lat);
        intpol_atm(ctl, atm, z, &p, &t, q, k);
        naux = refractivity(p, t);
        ng[i] = (naux - n) / h;
        xh[i] -= h;
      }
    } else
      for (i = 0; i < 3; i++)
        ng[i] = 0;

    /* Construct new tangent vector (second term)... */
    for (i = 0; i < 3; i++)
      ex1[i] += ds * ng[i];

    /* Normalize new tangent vector... */
    norm = NORM(ex1);
    for (i = 0; i < 3; i++)
      ex1[i] /= norm;

    /* Determine next point of LOS... */
    for (i = 0; i < 3; i++)
      x[i] += 0.5 * ds * (ex0[i] + ex1[i]);

    /* Copy tangent vector... */
    for (i = 0; i < 3; i++)
      ex0[i] = ex1[i];
  }

  /* Get tangent point (to be done before changing segment lengths!)... */
  tangent_point(los, &obs->tpz[ir], &obs->tplon[ir], &obs->
tplat[ir]);

  /* Change segment lengths according to trapezoid rule... */
  for (ip = los->np - 1; ip >= 1; ip--)
    los->ds[ip] = 0.5 * (los->ds[ip - 1] + los->ds[ip]);
  los->ds[0] *= 0.5;

  /* Compute column density... */
  for (ip = 0; ip < los->np; ip++)
    for (ig = 0; ig < ctl->ng; ig++)
      los->u[ig][ip] = 10 * los->q[ig][ip] * los->p[ip]
        / (GSL_CONST_MKSA_BOLTZMANN * los->t[ip]) * los->ds[ip];
}
```

Here is the call graph for this function:



5.13.2.34 void read_atm (const char * *dirname,* const char * *filename,* ctl_t * *ctl,* atm_t * *atm*)

Read atmospheric data.

Definition at line 4131 of file jurassic.c.

```
                {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int ig, iw;

  /* Init... */
  atm->np = 0;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read atmospheric data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", atm->time[atm->np]);
    TOK(NULL, tok, "%lg", atm->z[atm->np]);
    TOK(NULL, tok, "%lg", atm->lon[atm->np]);
    TOK(NULL, tok, "%lg", atm->lat[atm->np]);
    TOK(NULL, tok, "%lg", atm->p[atm->np]);
    TOK(NULL, tok, "%lg", atm->t[atm->np]);
    for (ig = 0; ig < ctl->ng; ig++)
      TOK(NULL, tok, "%lg", atm->q[ig][atm->np]);
    for (iw = 0; iw < ctl->nw; iw++)
      TOK(NULL, tok, "%lg", atm->k[iw][atm->np]);

    /* Increment data point counter... */
    if ((++atm->np) > NP)
      ERRMSG("Too many data points!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Could not read any data!");
}
```

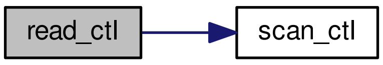
5.13.2.35 void read_ctl (int *argc,* char ∗ *argv[ ],* ctl_t ∗ *ctl*)

Read forward model control parameters.

Definition at line 4189 of file jurassic.c.

```
               {

  int id, ig, iw;

  /* Write info... */
  printf("\nJuelich Rapid Spectral Simulation Code (JURASSIC)\n"
         "(executable: %s | compiled: %s, %s)\n\n",
         argv[0], __DATE__, __TIME__);

  /* Emitters... */
  ctl->ng = (int) scan_ctl(argc, argv, "NG", -1, "0", NULL);
  if (ctl->ng < 0 || ctl->ng > NG)
    ERRMSG("Set 0 <= NG <= MAX!");
  for (ig = 0; ig < ctl->ng; ig++)
    scan_ctl(argc, argv, "EMITTER", ig, "", ctl->emitter[ig]);

  /* Radiance channels... */
  ctl->nd = (int) scan_ctl(argc, argv, "ND", -1, "0", NULL);
  if (ctl->nd < 0 || ctl->nd > ND)
    ERRMSG("Set 0 <= ND <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->nu[id] = scan_ctl(argc, argv, "NU", id, "", NULL);

  /* Spectral windows... */
  ctl->nw = (int) scan_ctl(argc, argv, "NW", -1, "1", NULL);
  if (ctl->nw < 0 || ctl->nw > NW)
    ERRMSG("Set 0 <= NW <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->window[id] = (int) scan_ctl(argc, argv, "WINDOW", id, "0", NULL);

  /* Emissivity look-up tables... */
  scan_ctl(argc, argv, "TBLBASE", -1, "-", ctl->tblbase);

  /* Hydrostatic equilibrium... */
  ctl->hydz = scan_ctl(argc, argv, "HYDZ", -1, "-999", NULL);

  /* Continua... */
  ctl->ctm_co2 = (int) scan_ctl(argc, argv, "CTM_CO2", -1, "1", NULL);
  ctl->ctm_h2o = (int) scan_ctl(argc, argv, "CTM_H2O", -1, "1", NULL);
  ctl->ctm_n2 = (int) scan_ctl(argc, argv, "CTM_N2", -1, "1", NULL);
  ctl->ctm_o2 = (int) scan_ctl(argc, argv, "CTM_O2", -1, "1", NULL);

  /* Ray-tracing... */
  ctl->refrac = (int) scan_ctl(argc, argv, "REFRAC", -1, "1", NULL);
  ctl->rayds = scan_ctl(argc, argv, "RAYDS", -1, "10", NULL);
  ctl->raydz = scan_ctl(argc, argv, "RAYDZ", -1, "0.5", NULL);

  /* Field of view... */
  scan_ctl(argc, argv, "FOV", -1, "-", ctl->fov);

  /* Retrieval interface... */
  ctl->retp_zmin = scan_ctl(argc, argv, "RETP_ZMIN", -1, "-999", NULL);
  ctl->retp_zmax = scan_ctl(argc, argv, "RETP_ZMAX", -1, "-999", NULL);
  ctl->rett_zmin = scan_ctl(argc, argv, "RETT_ZMIN", -1, "-999", NULL);
  ctl->rett_zmax = scan_ctl(argc, argv, "RETT_ZMAX", -1, "-999", NULL);
  for (ig = 0; ig < ctl->ng; ig++) {
    ctl->retq_zmin[ig] = scan_ctl(argc, argv, "RETQ_ZMIN", ig, "-999", NULL);
    ctl->retq_zmax[ig] = scan_ctl(argc, argv, "RETQ_ZMAX", ig, "-999", NULL);
  }
  for (iw = 0; iw < ctl->nw; iw++) {
    ctl->retk_zmin[iw] = scan_ctl(argc, argv, "RETK_ZMIN", iw, "-999", NULL);
    ctl->retk_zmax[iw] = scan_ctl(argc, argv, "RETK_ZMAX", iw, "-999", NULL);
  }

  /* Output flags... */
  ctl->write_bbt = (int) scan_ctl(argc, argv, "WRITE_BBT", -1, "0", NULL);
  ctl->write_matrix =
    (int) scan_ctl(argc, argv, "WRITE_MATRIX", -1, "0", NULL);
}
```

Here is the call graph for this function:



5.13.2.36 void read_matrix (const char ∗ *dirname*, const char ∗ *filename*, gsl_matrix ∗ *matrix*)

Read matrix.

Definition at line 4264 of file jurassic.c.

```
                        {

  FILE *in;

  char dum[LEN], file[LEN], line[LEN];

  double value;

  int i, j;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read matrix: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  gsl_matrix_set_zero(matrix);
  while (fgets(line, LEN, in))
    if (sscanf(line, "%d %s %s %s %s %s %d %s %s %s %s %s %lg",
               &i, dum, dum, dum, dum, dum,
               &j, dum, dum, dum, dum, dum, &value) == 13)
      gsl_matrix_set(matrix, (size_t) i, (size_t) j, value);

  /* Close file... */
  fclose(in);
}
```

5.13.2.37 void read_obs (const char ∗ *dirname,* const char ∗ *filename,* ctl_t ∗ *ctl,* obs_t ∗ *obs*)

Read observation data.

Definition at line 4304 of file jurassic.c.

```
                {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int id;

  /* Init... */
  obs->nr = 0;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read observation data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", obs->time[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obsz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplat[obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->rad[id][obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->tau[id][obs->nr]);

    /* Increment counter... */
    if ((++obs->nr) > NR)
      ERRMSG("Too many rays!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (obs->nr < 1)
    ERRMSG("Could not read any data!");
}
```

5.13.2.38 void read_shape (const char ∗ *filename,* double ∗ *x,* double ∗ *y,* int ∗ *n*)

Read shape function.

Definition at line 4366 of file jurassic.c.

```
          {

  FILE *in;

  char line[LEN];

  /* Write info... */
  printf("Read shape function: %s\n", filename);

  /* Open file... */
  if (!(in = fopen(filename, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  *n = 0;
  while (fgets(line, LEN, in))
    if (sscanf(line, "%lg %lg", &x[*n], &y[*n]) == 2)
      if ((++(*n)) > NSHAPE)
        ERRMSG("Too many data points!");

  /* Check number of points... */
  if (*n < 1)
    ERRMSG("Could not read any data!");

  /* Close file... */
  fclose(in);
}
```

5.13.2.39 double refractivity (double *p*, double *t*)

Compute refractivity (return value is n - 1).

Definition at line 4400 of file jurassic.c.

```
          {

  /* Refractivity of air at 4 to 15 micron... */
  return 7.753e-05 * p / t;
}
```

5.13.2.40 double scan_ctl (int *argc*, char ∗ *argv[ ]*, const char ∗ *varname*, int *arridx*, const char ∗ *defvalue*, char ∗ *value*)

Search control parameter file for variable entry.

Definition at line 4410 of file jurassic.c.

```
             {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (argv[1][0] != '-')
    if (!(in = fopen(argv[1], "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
    sprintf(value, "%s", rval);
  return atof(rval);
}
```

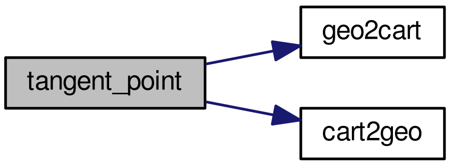
5.13.2.41 void tangent_point (los_t * *los,* double * *tpz,* double * *tplon,* double * *tplat*)

Find tangent point of a given LOS.

Definition at line 4481 of file jurassic.c.

```
                  {

  double a, b, c, dummy, v[3], v0[3], v2[3], x, x1, x2, yy0, yy1, yy2;

  size_t i, ip;

  /* Find minimum altitude... */
  ip = gsl_stats_min_index(los->z, 1, (size_t) los->np);

  /* Nadir or zenith... */
  if (ip <= 0 || ip >= (size_t) los->np - 1) {
    *tpz = los->z[los->np - 1];
    *tplon = los->lon[los->np - 1];
    *tplat = los->lat[los->np - 1];
  }

  /* Limb... */
  else {

    /* Determine interpolating polynomial y=a*x^2+b*x+c... */
    yy0 = los->z[ip - 1];
    yy1 = los->z[ip];
    yy2 = los->z[ip + 1];
    x1 = sqrt(gsl_pow_2(los->ds[ip]) - gsl_pow_2(yy1 - yy0));
    x2 = x1 + sqrt(gsl_pow_2(los->ds[ip + 1]) - gsl_pow_2(yy2 - yy1));
    a = 1 / (x1 - x2) * (-(yy0 - yy1) / x1 + (yy0 - yy2) / x2);
    b = -(yy0 - yy1) / x1 - a * x1;
    c = yy0;

    /* Get tangent point location... */
    x = -b / (2 * a);
    *tpz = a * x * x + b * x + c;
    geo2cart(los->z[ip - 1], los->lon[ip - 1], los->lat[ip - 1], v0);
    geo2cart(los->z[ip + 1], los->lon[ip + 1], los->lat[ip + 1], v2);
    for (i = 0; i < 3; i++)
      v[i] = LIN(0.0, v0[i], x2, v2[i], x);
    cart2geo(v, &dummy, tplon, tplat);
  }
}
```

Here is the call graph for this function:



5.13.2.42 void time2jsec (int *year*, int *mon*, int *day*, int *hour*, int *min*, int *sec*, double *remain*, double ∗ *jsec*)

Convert date to seconds.

Definition at line 4527 of file jurassic.c.

```
                {

  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}
```

5.13.2.43 void timer (const char ∗ *name*, const char ∗ *file*, const char ∗ *func*, int *line*, int *mode*)

Measure wall-clock time.

Definition at line 4558 of file jurassic.c.

```
            {

  static double dt_w, w0[10];

  static int l0[10], nt;

  struct timeval tim;

  /* Start new timer... */
  if (mode == 1) {
    gettimeofday(&tim, NULL);
    w0[nt] = (double) tim.tv_sec + (double) tim.tv_usec / 1e6;
    l0[nt] = line;
    if ((++nt) >= 10)
      ERRMSG("Too many timers!");
  }

  /* Write elapsed time... */
  else {

    /* Check timer index... */
    if (nt - 1 < 0)
      ERRMSG("Coding error!");

    /* Get time differences... */
    gettimeofday(&tim, NULL);
    dt_w = (double) tim.tv_sec + (double) tim.tv_usec / 1e6 - w0[nt - 1];

    /* Write elapsed time... */
    printf("Timer '%s' (%s, %s, l%d-%d): %.3f sec\n",
           name, file, func, l0[nt - 1], line, dt_w);
  }

  /* Stop timer... */
  if (mode == 3)
    nt--;
}
```

5.13.2.44 void write_atm (const char ∗ *dirname,* const char ∗ *filename,* ctl_t ∗ *ctl,* atm_t ∗ *atm*)

Write atmospheric data.

Definition at line 4603 of file jurassic.c.

```
               {

  FILE *out;

  char file[LEN];

  int ig, ip, iw, n = 6;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write atmospheric data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n" "# $6 = temperature [K]\n");
  for (ig = 0; ig < ctl->ng; ig++)
    fprintf(out, "# $%d = %s volume mixing ratio\n", ++n, ctl->emitter[ig]);
  for (iw = 0; iw < ctl->nw; iw++)
    fprintf(out, "# $%d = window %d: extinction [1/km]\n", ++n, iw);

  /* Write data... */
  for (ip = 0; ip < atm->np; ip++) {
    if (ip == 0 || atm->lat[ip] != atm->lat[ip - 1]
        || atm->lon[ip] != atm->lon[ip - 1])
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g", atm->time[ip], atm->z[ip],
            atm->lon[ip], atm->lat[ip], atm->p[ip], atm->t[ip]);
    for (ig = 0; ig < ctl->ng; ig++)
      fprintf(out, " %g", atm->q[ig][ip]);
    for (iw = 0; iw < ctl->nw; iw++)
      fprintf(out, " %g", atm->k[iw][ip]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}
```

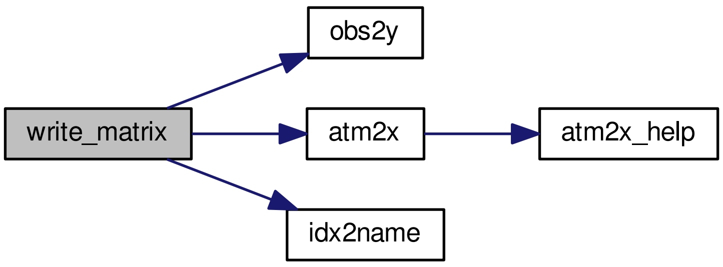
5.13.2.45 void write_matrix (const char ∗ *dirname,* const char ∗ *filename,* ctl_t ∗ *ctl,* gsl_matrix ∗ *matrix,* atm_t ∗ *atm,* obs_t ∗ *obs,* const char ∗ *rowspace,* const char ∗ *colspace,* const char ∗ *sort*)

Write matrix.

Definition at line 4660 of file jurassic.c.

```
                    {

  FILE *out;

  char file[LEN], quantity[LEN];

  int *cida, *ciqa, *cipa, *cira, *rida, *riqa, *ripa, *rira;

  size_t i, j, nc, nr;

  /* Check output flag... */
  if (!ctl->write_matrix)
    return;

  /* Allocate... */
  ALLOC(cida, int, M);
  ALLOC(ciqa, int,
        N);
  ALLOC(cipa, int,
        N);
  ALLOC(cira, int,
        M);
  ALLOC(rida, int,
        M);
  ALLOC(riqa, int,
        N);
  ALLOC(ripa, int,
        N);
  ALLOC(rira, int,
        M);

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write matrix: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header (row space)... */
  if (rowspace[0] == 'y') {

    fprintf(out,
            "# $1 = Row: index (measurement space)\n"
            "# $2 = Row: channel wavenumber [cm^-1]\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: view point altitude [km]\n"
            "# $5 = Row: view point longitude [deg]\n"
            "# $6 = Row: view point latitude [deg]\n");

    /* Get number of rows... */
    nr = obs2y(ctl, obs, NULL, rida, rira);

  } else {

    fprintf(out,
            "# $1 = Row: index (state space)\n"
            "# $2 = Row: name of quantity\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: altitude [km]\n"
            "# $5 = Row: longitude [deg]\n" "# $6 = Row: latitude [deg]\n");

    /* Get number of rows... */
    nr = atm2x(ctl, atm, NULL, riqa, ripa);
  }

  /* Write header (column space)... */
  if (colspace[0] == 'y') {

    fprintf(out,
            "# $7 = Col: index (measurement space)\n"
            "# $8 = Col: channel wavenumber [cm^-1]\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: view point altitude [km]\n"
            "# $11 = Col: view point longitude [deg]\n"
            "# $12 = Col: view point latitude [deg]\n");

    /* Get number of columns... */
    nc = obs2y(ctl, obs, NULL, cida, cira);

  } else {

    fprintf(out,
            "# $7 = Col: index (state space)\n"
            "# $8 = Col: name of quantity\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: altitude [km]\n"
            "# $11 = Col: longitude [deg]\n" "# $12 = Col: latitude [deg]\n");

    /* Get number of columns... */
    nc = atm2x(ctl, atm, NULL, ciqa, cipa);
  }

  /* Write header entry... */
  fprintf(out, "# $13 = Matrix element\n\n");

  /* Write matrix data... */
  i = j = 0;
  while (i < nr && j < nc) {

    /* Write info about the row... */
    if (rowspace[0] == 'y')
      fprintf(out, "%d %g %.2f %g %g %g",
              (int) i, ctl->nu[rida[i]],
              obs->time[rira[i]], obs->vpz[rira[i]],
              obs->vplon[rira[i]], obs->vplat[rira[i]]);
    else {
      idx2name(ctl, riqa[i], quantity);
      fprintf(out, "%d %s %.2f %g %g %g", (int) i, quantity,
              atm->time[ripa[i]], atm->z[ripa[i]],
              atm->lon[ripa[i]], atm->lat[ripa[i]]);
    }

    /* Write info about the column... */
    if (colspace[0] == 'y')
      fprintf(out, " %d %g %.2f %g %g %g",
              (int) j, ctl->nu[cida[j]],
              obs->time[cira[j]], obs->vpz[cira[j]],
              obs->vplon[cira[j]], obs->vplat[cira[j]]);
    else {
      idx2name(ctl, ciqa[j], quantity);
      fprintf(out, " %d %s %.2f %g %g %g", (int) j, quantity,
              atm->time[cipa[j]], atm->z[cipa[j]],
              atm->lon[cipa[j]], atm->lat[cipa[j]]);
    }

    /* Write matrix entry... */
    fprintf(out, " %g\n", gsl_matrix_get(matrix, i, j));

    /* Set matrix indices... */
    if (sort[0] == 'r') {
      j++;
      if (j >= nc) {
        j = 0;
        i++;
        fprintf(out, "\n");
      }
    } else {
      i++;
      if (i >= nr) {
        i = 0;
        j++;
        fprintf(out, "\n");
      }
    }
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(cida);
  free(ciqa);
  free(cipa);
  free(cira);
  free(rida);
  free(riqa);
  free(ripa);
  free(rira);
}
```

Here is the call graph for this function:



5.13.2.46 void write_obs (const char * *dirname*, const char * *filename*, ctl_t * *ctl*, obs_t * *obs*)

Write observation data.

Definition at line 4837 of file jurassic.c.

```
                {

  FILE *out;

  char file[LEN];

  int id, ir, n = 10;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write observation data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = observer altitude [km]\n"
          "# $3 = observer longitude [deg]\n"
          "# $4 = observer latitude [deg]\n"
          "# $5 = view point altitude [km]\n"
          "# $6 = view point longitude [deg]\n"
          "# $7 = view point latitude [deg]\n"
          "# $8 = tangent point altitude [km]\n"
          "# $9 = tangent point longitude [deg]\n"
          "# $10 = tangent point latitude [deg]\n");
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: radiance [W/(m^2 sr cm^-1)]\n",
            ++n, ctl->nu[id]);
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: transmittance\n", ++n, ctl->nu[id]);

  /* Write data... */
  for (ir = 0; ir < obs->nr; ir++) {
    if (ir == 0 || obs->time[ir] != obs->time[ir - 1])
```

```
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g", obs->time[ir],
            obs->obsz[ir], obs->obslon[ir], obs->obslat[ir],
            obs->vpz[ir], obs->vplon[ir], obs->vplat[ir],
            obs->tpz[ir], obs->tplon[ir], obs->tplat[ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->rad[id][ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->tau[id][ir]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}
```

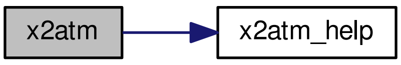
5.13.2.47 void x2atm (ctl_t * *ctl,* gsl_vector * *x,* atm_t * *atm*)

Decompose parameter vector or state vector.

Definition at line 4901 of file jurassic.c.

```
                  {

  int ig, iw;

  size_t n = 0;

  /* Set pressure... */
  x2atm_help(atm, ctl->retp_zmin, ctl->retp_zmax, atm->
p, x, &n);

  /* Set temperature... */
  x2atm_help(atm, ctl->rett_zmin, ctl->rett_zmax, atm->
t, x, &n);

  /* Set volume mixing ratio... */
  for (ig = 0; ig < ctl->ng; ig++)
    x2atm_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], x, &n);

  /* Set extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    x2atm_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], x, &n);
}
```

Here is the call graph for this function:



5.13.2.48 void x2atm_help (atm_t * *atm,* double *zmin,* double *zmax,* double * *value,* gsl_vector * *x,* size_t * *n*)

Extract elements from state vector.

Definition at line 4929 of file jurassic.c.

```
                 {

  int ip;

  /* Extract state vector elements... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      value[ip] = gsl_vector_get(x, *n);
      (*n)++;
    }
}
```

5.13.2.49 void y2obs (ctl_t * ctl, gsl_vector * y, obs_t * obs)

Decompose measurement vector.

Definition at line 4949 of file jurassic.c.

```
                {

  int id, ir;

  size_t m = 0;

  /* Decompose measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        obs->rad[id][ir] = gsl_vector_get(y, m);
        m++;
      }
}
```

5.14 jurassic.c

```
/*
  This file is part of JURASSIC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

/*****************************************************************************/

size_t atm2x(
  ctl_t * ctl,
  atm_t * atm,
  gsl_vector * x,
  int *iqa,
  int *ipa) {

  int ig, iw;

  size_t n = 0;

  /* Add pressure... */
  atm2x_help(atm, ctl->retp_zmin, ctl->retp_zmax,
             atm->p, IDXP, x, iqa, ipa, &n);

  /* Add temperature... */
  atm2x_help(atm, ctl->rett_zmin, ctl->rett_zmax,
             atm->t, IDXT, x, iqa, ipa, &n);

  /* Add volume mixing ratios... */
  for (ig = 0; ig < ctl->ng; ig++)
    atm2x_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], IDXQ(ig), x, iqa, ipa, &n);

  /* Add extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    atm2x_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], IDXK(iw), x, iqa, ipa, &n);

  return n;
}

/*****************************************************************************/
```

```

void atm2x_help(
  atm_t * atm,
  double zmin,
  double zmax,
  double *value,
  int val_iqa,
  gsl_vector * x,
  int *iqa,
  int *ipa,
  size_t * n) {

  int ip;

  /* Add elements to state vector... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      if (x != NULL)
        gsl_vector_set(x, *n, value[ip]);
      if (iqa != NULL)
        iqa[*n] = val_iqa;
      if (ipa != NULL)
        ipa[*n] = ip;
      (*n)++;
    }
}

/*****************************************************************************/

double brightness(
  double rad,
  double nu) {

  return C2 * nu / gsl_log1p(C1 * gsl_pow_3(nu) / rad);
}


/*****************************************************************************/

void cart2geo(
  double *x,
  double *z,
  double *lon,
  double *lat) {

  double radius;

  radius = NORM(x);
  *lat = asin(x[2] / radius) * 180 / M_PI;
  *lon = atan2(x[1], x[0]) * 180 / M_PI;
  *z = radius - RE;
}

/*****************************************************************************/

void climatology(
  ctl_t * ctl,
  atm_t * atm) {

  static double z[121] = {
    0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
    20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37,
    38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
    56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73,
    74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91,
    92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107,
    108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120
  };

  static double pre[121] = {
    1017, 901.083, 796.45, 702.227, 617.614, 541.644, 473.437, 412.288,
    357.603, 308.96, 265.994, 228.348, 195.619, 167.351, 143.039, 122.198,
    104.369, 89.141, 76.1528, 65.0804, 55.641, 47.591, 40.7233, 34.8637,
    29.8633, 25.5956, 21.9534, 18.8445, 16.1909, 13.9258, 11.9913,
    10.34, 8.92988, 7.72454, 6.6924, 5.80701, 5.04654, 4.39238, 3.82902,
    3.34337, 2.92413, 2.56128, 2.2464, 1.97258, 1.73384, 1.52519, 1.34242,
    1.18197, 1.04086, 0.916546, 0.806832, 0.709875, 0.624101, 0.548176,
    0.480974, 0.421507, 0.368904, 0.322408, 0.281386, 0.245249, 0.213465,
    0.185549, 0.161072, 0.139644, 0.120913, 0.104568, 0.0903249, 0.0779269,
    0.0671493, 0.0577962, 0.0496902, 0.0426736, 0.0366093, 0.0313743,
    0.0268598, 0.0229699, 0.0196206, 0.0167399, 0.0142646, 0.0121397,
    0.0103181, 0.00875775, 0.00742226, 0.00628076, 0.00530519, 0.00447183,
    0.00376124, 0.00315632, 0.00264248, 0.00220738, 0.00184003, 0.00153095,
    0.00127204, 0.00105608, 0.000876652, 0.00072798, 0.00060492,
    0.000503201, 0.000419226, 0.000349896, 0.000292659, 0.000245421,
    0.000206394, 0.000174125, 0.000147441, 0.000125333, 0.000106985,
    9.173e-05, 7.90172e-05, 6.84172e-05, 5.95574e-05, 5.21183e-05,
  4.58348e-05, 4.05127e-05, 3.59987e-05, 3.21583e-05, 2.88718e-05,
  2.60322e-05, 2.35687e-05, 2.14263e-05, 1.95489e-05
};

static double tem[121] = {
  285.14, 279.34, 273.91, 268.3, 263.24, 256.55, 250.2, 242.82, 236.17,
  229.87, 225.04, 221.19, 218.85, 217.19, 216.2, 215.68, 215.42, 215.55,
  215.92, 216.4, 216.93, 217.45, 218, 218.68, 219.39, 220.25, 221.3,
  222.41, 223.88, 225.42, 227.2, 229.52, 231.89, 234.51, 236.85, 239.42,
  241.94, 244.57, 247.36, 250.32, 253.34, 255.82, 258.27, 260.39,
  262.03, 263.45, 264.2, 264.78, 264.67, 264.38, 263.24, 262.03, 260.02,
  258.09, 255.63, 253.28, 250.43, 247.81, 245.26, 242.77, 240.38,
  237.94, 235.79, 233.53, 231.5, 229.53, 227.6, 225.62, 223.77, 222.06,
  220.33, 218.69, 217.18, 215.64, 214.13, 212.52, 210.86, 209.25,
  207.49, 205.81, 204.11, 202.22, 200.32, 198.39, 195.92, 193.46,
  190.94, 188.31, 185.82, 183.57, 181.43, 179.74, 178.64, 178.1, 178.25,
  178.7, 179.41, 180.67, 182.31, 184.18, 186.6, 189.53, 192.66, 196.54,
  201.13, 205.93, 211.73, 217.86, 225, 233.53, 242.57, 252.14, 261.48,
  272.97, 285.26, 299.12, 312.2, 324.17, 338.34, 352.56, 365.28
};

static double c2h2[121] = {
  1.352e-09, 2.83e-10, 1.269e-10, 6.926e-11, 4.346e-11, 2.909e-11,
  2.014e-11, 1.363e-11, 8.71e-12, 5.237e-12, 2.718e-12, 1.375e-12,
  5.786e-13, 2.16e-13, 7.317e-14, 2.551e-14, 1.055e-14, 4.758e-15,
  2.056e-15, 7.703e-16, 2.82e-16, 1.035e-16, 4.382e-17, 1.946e-17,
  9.638e-18, 5.2e-18, 2.811e-18, 1.494e-18, 7.925e-19, 4.213e-19,
  1.998e-19, 8.78e-20, 3.877e-20, 1.728e-20, 7.743e-21, 3.536e-21,
  1.623e-21, 7.508e-22, 3.508e-22, 1.65e-22, 7.837e-23, 3.733e-23,
  1.808e-23, 8.77e-24, 4.285e-24, 2.095e-24, 1.032e-24, 5.082e-25,
  2.506e-25, 1.236e-25, 6.088e-26, 2.996e-26, 1.465e-26, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double c2h6[121] = {
  2.667e-09, 2.02e-09, 1.658e-09, 1.404e-09, 1.234e-09, 1.109e-09,
  1.012e-09, 9.262e-10, 8.472e-10, 7.71e-10, 6.932e-10, 6.216e-10,
  5.503e-10, 4.87e-10, 4.342e-10, 3.861e-10, 3.347e-10, 2.772e-10,
  2.209e-10, 1.672e-10, 1.197e-10, 8.536e-11, 5.783e-11, 3.846e-11,
  2.495e-11, 1.592e-11, 1.017e-11, 6.327e-12, 3.895e-12, 2.403e-12,
  1.416e-12, 8.101e-13, 4.649e-13, 2.686e-13, 1.557e-13, 9.14e-14,
  5.386e-14, 3.19e-14, 1.903e-14, 1.14e-14, 6.875e-15, 4.154e-15,
  2.538e-15, 1.553e-15, 9.548e-16, 5.872e-16, 3.63e-16, 2.244e-16,
  1.388e-16, 8.587e-17, 5.308e-17, 3.279e-17, 2.017e-17, 1.238e-17,
  7.542e-18, 4.585e-18, 2.776e-18, 1.671e-18, 9.985e-19, 5.937e-19,
  3.518e-19, 2.07e-19, 1.215e-19, 7.06e-20, 4.097e-20, 2.37e-20,
  1.363e-20, 7.802e-21, 4.441e-21, 2.523e-21, 1.424e-21, 8.015e-22,
  4.497e-22, 2.505e-22, 1.391e-22, 7.691e-23, 4.238e-23, 2.331e-23,
  1.274e-23, 6.929e-24, 3.752e-24, 2.02e-24, 1.083e-24, 5.774e-25,
  3.041e-25, 1.593e-25, 8.308e-26, 4.299e-26, 2.195e-26, 1.112e-26,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double ccl4[121] = {
  1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10,
  1.075e-10, 1.075e-10, 1.075e-10, 1.06e-10, 1.024e-10, 9.69e-11,
  8.93e-11, 8.078e-11, 7.213e-11, 6.307e-11, 5.383e-11, 4.49e-11,
  3.609e-11, 2.705e-11, 1.935e-11, 1.385e-11, 8.35e-12, 5.485e-12,
  3.853e-12, 2.22e-12, 5.875e-13, 3.445e-13, 1.015e-13, 6.075e-14,
  4.383e-14, 2.692e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14
};

static double ch4[121] = {
  1.864e-06, 1.835e-06, 1.819e-06, 1.805e-06, 1.796e-06, 1.788e-06,
  1.782e-06, 1.776e-06, 1.769e-06, 1.761e-06, 1.749e-06, 1.734e-06,
  1.716e-06, 1.692e-06, 1.654e-06, 1.61e-06, 1.567e-06, 1.502e-06,
  1.433e-06, 1.371e-06, 1.323e-06, 1.277e-06, 1.232e-06, 1.188e-06,
  1.147e-06, 1.108e-06, 1.07e-06, 1.027e-06, 9.854e-07, 9.416e-07,
  8.933e-07, 8.478e-07, 7.988e-07, 7.515e-07, 7.07e-07, 6.64e-07,
  6.239e-07, 5.864e-07, 5.512e-07, 5.184e-07, 4.87e-07, 4.571e-07,
  4.296e-07, 4.04e-07, 3.802e-07, 3.578e-07, 3.383e-07, 3.203e-07,
  3.032e-07, 2.889e-07, 2.76e-07, 2.635e-07, 2.519e-07, 2.409e-07,
  2.302e-07, 2.219e-07, 2.144e-07, 2.071e-07, 1.999e-07, 1.93e-07,
  1.862e-07, 1.795e-07, 1.731e-07, 1.668e-07, 1.607e-07, 1.548e-07,
  1.49e-07, 1.434e-07, 1.38e-07, 1.328e-07, 1.277e-07, 1.227e-07,
  1.18e-07, 1.134e-07, 1.089e-07, 1.046e-07, 1.004e-07, 9.635e-08,
  9.245e-08, 8.867e-08, 8.502e-08, 8.15e-08, 7.809e-08, 7.48e-08,
  7.159e-08, 6.849e-08, 6.55e-08, 6.262e-08, 5.98e-08, 5.708e-08,
  5.448e-08, 5.194e-08, 4.951e-08, 4.72e-08, 4.5e-08, 4.291e-08,
  4.093e-08, 3.905e-08, 3.729e-08, 3.563e-08, 3.408e-08, 3.265e-08,
  3.128e-08, 2.996e-08, 2.87e-08, 2.76e-08, 2.657e-08, 2.558e-08,
  2.467e-08, 2.385e-08, 2.307e-08, 2.234e-08, 2.168e-08, 2.108e-08,
  2.05e-08, 1.998e-08, 1.947e-08, 1.902e-08, 1.86e-08, 1.819e-08,
  1.782e-08
};

static double clo[121] = {
  7.419e-15, 1.061e-14, 1.518e-14, 2.195e-14, 3.175e-14, 4.666e-14,
  6.872e-14, 1.03e-13, 1.553e-13, 2.375e-13, 3.664e-13, 5.684e-13,
  8.915e-13, 1.402e-12, 2.269e-12, 4.125e-12, 7.501e-12, 1.257e-11,
  2.048e-11, 3.338e-11, 5.44e-11, 8.846e-11, 1.008e-10, 1.082e-10,
  1.157e-10, 1.232e-10, 1.312e-10, 1.539e-10, 1.822e-10, 2.118e-10,
  2.387e-10, 2.687e-10, 2.875e-10, 3.031e-10, 3.23e-10, 3.648e-10,
  4.117e-10, 4.477e-10, 4.633e-10, 4.794e-10, 4.95e-10, 5.104e-10,
  5.259e-10, 5.062e-10, 4.742e-10, 4.443e-10, 4.051e-10, 3.659e-10,
  3.305e-10, 2.911e-10, 2.54e-10, 2.215e-10, 1.927e-10, 1.675e-10,
  1.452e-10, 1.259e-10, 1.09e-10, 9.416e-11, 8.119e-11, 6.991e-11,
  6.015e-11, 5.163e-11, 4.43e-11, 3.789e-11, 3.24e-11, 2.769e-11,
  2.361e-11, 2.011e-11, 1.71e-11, 1.453e-11, 1.233e-11, 1.045e-11,
  8.851e-12, 7.48e-12, 6.316e-12, 5.326e-12, 4.487e-12, 3.778e-12,
  3.176e-12, 2.665e-12, 2.234e-12, 1.87e-12, 1.563e-12, 1.304e-12,
  1.085e-12, 9.007e-13, 7.468e-13, 6.179e-13, 5.092e-13, 4.188e-13,
  3.442e-13, 2.816e-13, 2.304e-13, 1.885e-13, 1.542e-13, 1.263e-13,
  1.035e-13, 8.5e-14, 7.004e-14, 5.783e-14, 4.795e-14, 4.007e-14,
  3.345e-14, 2.792e-14, 2.33e-14, 1.978e-14, 1.686e-14, 1.438e-14,
  1.234e-14, 1.07e-14, 9.312e-15, 8.131e-15, 7.164e-15, 6.367e-15,
  5.67e-15, 5.088e-15, 4.565e-15, 4.138e-15, 3.769e-15, 3.432e-15,
  3.148e-15
};

static double clono2[121] = {
  1.011e-13, 1.515e-13, 2.272e-13, 3.446e-13, 5.231e-13, 8.085e-13,
  1.253e-12, 1.979e-12, 3.149e-12, 5.092e-12, 8.312e-12, 1.366e-11,
  2.272e-11, 3.791e-11, 6.209e-11, 9.101e-11, 1.334e-10, 1.951e-10,
  2.853e-10, 3.94e-10, 4.771e-10, 5.771e-10, 6.675e-10, 7.665e-10,
  8.504e-10, 8.924e-10, 9.363e-10, 8.923e-10, 8.411e-10, 7.646e-10,
  6.525e-10, 5.576e-10, 4.398e-10, 3.403e-10, 2.612e-10, 1.915e-10,
  1.407e-10, 1.028e-10, 7.455e-11, 5.42e-11, 3.708e-11, 2.438e-11,
  1.618e-11, 1.075e-11, 7.17e-12, 4.784e-12, 3.205e-12, 2.147e-12,
  1.44e-12, 9.654e-13, 6.469e-13, 4.332e-13, 2.891e-13, 1.926e-13,
  1.274e-13, 8.422e-14, 5.547e-14, 3.636e-14, 2.368e-14, 1.536e-14,
  9.937e-15, 6.39e-15, 4.101e-15, 2.61e-15, 1.659e-15, 1.052e-15,
  6.638e-16, 4.172e-16, 2.61e-16, 1.63e-16, 1.013e-16, 6.275e-17,
  3.879e-17, 2.383e-17, 1.461e-17, 8.918e-18, 5.43e-18, 3.301e-18,
  1.997e-18, 1.203e-18, 7.216e-19, 4.311e-19, 2.564e-19, 1.519e-19,
  8.911e-20, 5.203e-20, 3.026e-20, 1.748e-20, 9.99e-21, 5.673e-21,
  3.215e-21, 1.799e-21, 1.006e-21, 5.628e-22, 3.146e-22, 1.766e-22,
  9.94e-23, 5.614e-23, 3.206e-23, 1.841e-23, 1.071e-23, 6.366e-24,
  3.776e-24, 2.238e-24, 1.326e-24, 8.253e-25, 5.201e-25, 3.279e-25,
  2.108e-25, 1.395e-25, 9.326e-26, 6.299e-26, 4.365e-26, 3.104e-26,
  2.219e-26, 1.621e-26, 1.185e-26, 8.92e-27, 6.804e-27, 5.191e-27,
  4.041e-27
};

static double co[121] = {
  1.907e-07, 1.553e-07, 1.362e-07, 1.216e-07, 1.114e-07, 1.036e-07,
  9.737e-08, 9.152e-08, 8.559e-08, 7.966e-08, 7.277e-08, 6.615e-08,
  5.884e-08, 5.22e-08, 4.699e-08, 4.284e-08, 3.776e-08, 3.274e-08,
  2.845e-08, 2.479e-08, 2.246e-08, 2.054e-08, 1.991e-08, 1.951e-08,
  1.94e-08, 2.009e-08, 2.1e-08, 2.201e-08, 2.322e-08, 2.45e-08,
  2.602e-08, 2.73e-08, 2.867e-08, 2.998e-08, 3.135e-08, 3.255e-08,
  3.352e-08, 3.426e-08, 3.484e-08, 3.53e-08, 3.593e-08, 3.671e-08,
  3.759e-08, 3.945e-08, 4.192e-08, 4.49e-08, 5.03e-08, 5.703e-08,
  6.538e-08, 7.878e-08, 9.644e-08, 1.196e-07, 1.498e-07, 1.904e-07,
  2.422e-07, 3.055e-07, 3.804e-07, 4.747e-07, 5.899e-07, 7.272e-07,
  8.91e-07, 1.071e-06, 1.296e-06, 1.546e-06, 1.823e-06, 2.135e-06,
  2.44e-06, 2.714e-06, 2.967e-06, 3.189e-06, 3.391e-06, 3.58e-06,
  3.773e-06, 4.022e-06, 4.346e-06, 4.749e-06, 5.199e-06, 5.668e-06,
  6.157e-06, 6.688e-06, 7.254e-06, 7.867e-06, 8.539e-06, 9.26e-06,
  1.009e-05, 1.119e-05, 1.228e-05, 1.365e-05, 1.506e-05, 1.641e-05,
  1.784e-05, 1.952e-05, 2.132e-05, 2.323e-05, 2.531e-05, 2.754e-05,
  3.047e-05, 3.459e-05, 3.922e-05, 4.439e-05, 4.825e-05, 5.077e-05,
  5.34e-05, 5.618e-05, 5.909e-05, 6.207e-05, 6.519e-05, 6.845e-05,
  6.819e-05, 6.726e-05, 6.622e-05, 6.512e-05, 6.671e-05, 6.862e-05,
  7.048e-05, 7.264e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05
};

static double cof2[121] = {
  7.5e-14, 1.055e-13, 1.485e-13, 2.111e-13, 3.001e-13, 4.333e-13,
  6.269e-13, 9.221e-13, 1.364e-12, 2.046e-12, 3.093e-12, 4.703e-12,
  7.225e-12, 1.113e-11, 1.66e-11, 2.088e-11, 2.626e-11, 3.433e-11,
  4.549e-11, 5.886e-11, 7.21e-11, 8.824e-11, 1.015e-10, 1.155e-10,
  1.288e-10, 1.388e-10, 1.497e-10, 1.554e-10, 1.606e-10, 1.639e-10,
  1.64e-10, 1.64e-10, 1.596e-10, 1.542e-10, 1.482e-10, 1.382e-10,
  1.289e-10, 1.198e-10, 1.109e-10, 1.026e-10, 9.484e-11, 8.75e-11,
  8.086e-11, 7.49e-11, 6.948e-11, 6.446e-11, 5.961e-11, 5.505e-11,
  5.085e-11, 4.586e-11, 4.1e-11, 3.665e-11, 3.235e-11, 2.842e-11,
  2.491e-11, 2.11e-11, 1.769e-11, 1.479e-11, 1.197e-11, 9.631e-12,
  7.74e-12, 6.201e-12, 4.963e-12, 3.956e-12, 3.151e-12, 2.507e-12,
  1.99e-12, 1.576e-12, 1.245e-12, 9.83e-13, 7.742e-13, 6.088e-13,
  4.782e-13, 3.745e-13, 2.929e-13, 2.286e-13, 1.782e-13, 1.388e-13,
  1.079e-13, 8.362e-14, 6.471e-14, 4.996e-14, 3.85e-14, 2.96e-14,
  2.265e-14, 1.729e-14, 1.317e-14, 9.998e-15, 7.549e-15, 5.683e-15,
  4.273e-15, 3.193e-15, 2.385e-15, 1.782e-15, 1.331e-15, 9.957e-16,
  7.461e-16, 5.601e-16, 4.228e-16, 3.201e-16, 2.438e-16, 1.878e-16,
  1.445e-16, 1.111e-16, 8.544e-17, 6.734e-17, 5.341e-17, 4.237e-17,
  3.394e-17, 2.759e-17, 2.254e-17, 1.851e-17, 1.54e-17, 1.297e-17,
  1.096e-17, 9.365e-18, 8e-18, 6.938e-18, 6.056e-18, 5.287e-18,
  4.662e-18
};

static double f11[121] = {
  2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10,
  2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.635e-10, 2.536e-10,
  2.44e-10, 2.348e-10, 2.258e-10, 2.153e-10, 2.046e-10, 1.929e-10,
  1.782e-10, 1.648e-10, 1.463e-10, 1.291e-10, 1.1e-10, 8.874e-11,
  7.165e-11, 5.201e-11, 3.744e-11, 2.577e-11, 1.64e-11, 1.048e-11,
  5.993e-12, 3.345e-12, 1.839e-12, 9.264e-13, 4.688e-13, 2.329e-13,
  1.129e-13, 5.505e-14, 2.825e-14, 1.492e-14, 7.997e-15, 5.384e-15,
  3.988e-15, 2.955e-15, 2.196e-15, 1.632e-15, 1.214e-15, 9.025e-16,
  6.708e-16, 4.984e-16, 3.693e-16, 2.733e-16, 2.013e-16, 1.481e-16,
  1.087e-16, 7.945e-17, 5.782e-17, 4.195e-17, 3.038e-17, 2.19e-17,
  1.577e-17, 1.128e-17, 8.063e-18, 5.753e-18, 4.09e-18, 2.899e-18,
  2.048e-18, 1.444e-18, 1.015e-18, 7.12e-19, 4.985e-19, 3.474e-19,
  2.417e-19, 1.677e-19, 1.161e-19, 8.029e-20, 5.533e-20, 3.799e-20,
  2.602e-20, 1.776e-20, 1.209e-20, 8.202e-21, 5.522e-21, 3.707e-21,
  2.48e-21, 1.652e-21, 1.091e-21, 7.174e-22, 4.709e-22, 3.063e-22,
  1.991e-22, 1.294e-22, 8.412e-23, 5.483e-23, 3.581e-23, 2.345e-23,
  1.548e-23, 1.027e-23, 6.869e-24, 4.673e-24, 3.173e-24, 2.153e-24,
  1.461e-24, 1.028e-24, 7.302e-25, 5.188e-25, 3.739e-25, 2.753e-25,
  2.043e-25, 1.528e-25, 1.164e-25, 9.041e-26, 7.051e-26, 5.587e-26,
  4.428e-26, 3.588e-26, 2.936e-26, 2.402e-26, 1.995e-26
};

static double f12[121] = {
  5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10,
  5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.429e-10, 5.291e-10,
  5.155e-10, 5.022e-10, 4.893e-10, 4.772e-10, 4.655e-10, 4.497e-10,
  4.249e-10, 4.015e-10, 3.632e-10, 3.261e-10, 2.858e-10, 2.408e-10,
  2.03e-10, 1.685e-10, 1.4e-10, 1.163e-10, 9.65e-11, 8.02e-11, 6.705e-11,
  5.624e-11, 4.764e-11, 4.249e-11, 3.792e-11, 3.315e-11, 2.819e-11,
  2.4e-11, 1.999e-11, 1.64e-11, 1.352e-11, 1.14e-11, 9.714e-12,
  8.28e-12, 7.176e-12, 6.251e-12, 5.446e-12, 4.72e-12, 4.081e-12,
  3.528e-12, 3.08e-12, 2.699e-12, 2.359e-12, 2.111e-12, 1.901e-12,
  1.709e-12, 1.534e-12, 1.376e-12, 1.233e-12, 1.103e-12, 9.869e-13,
  8.808e-13, 7.859e-13, 7.008e-13, 6.241e-13, 5.553e-13, 4.935e-13,
  4.383e-13, 3.889e-13, 3.447e-13, 3.054e-13, 2.702e-13, 2.389e-13,
  2.11e-13, 1.862e-13, 1.643e-13, 1.448e-13, 1.274e-13, 1.121e-13,
  9.844e-14, 8.638e-14, 7.572e-14, 6.62e-14, 5.782e-14, 5.045e-14,
  4.394e-14, 3.817e-14, 3.311e-14, 2.87e-14, 2.48e-14, 2.142e-14,
  1.851e-14, 1.599e-14, 1.383e-14, 1.196e-14, 1.036e-14, 9e-15,
  7.828e-15, 6.829e-15, 5.992e-15, 5.254e-15, 4.606e-15, 4.037e-15,
  3.583e-15, 3.19e-15, 2.841e-15, 2.542e-15, 2.291e-15, 2.07e-15,
  1.875e-15, 1.71e-15, 1.57e-15, 1.442e-15, 1.333e-15, 1.232e-15,
  1.147e-15, 1.071e-15, 1.001e-15, 9.396e-16
};

static double f14[121] = {
  9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11,
  9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 8.91e-11, 8.73e-11, 8.46e-11,
  8.19e-11, 7.92e-11, 7.74e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
  7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11
};

static double f22[121] = {
  1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10,
    1.4e-10, 1.4e-10, 1.4e-10, 1.372e-10, 1.317e-10, 1.235e-10, 1.153e-10,
    1.075e-10, 1.002e-10, 9.332e-11, 8.738e-11, 8.194e-11, 7.7e-11,
    7.165e-11, 6.753e-11, 6.341e-11, 5.971e-11, 5.6e-11, 5.229e-11,
    4.859e-11, 4.488e-11, 4.118e-11, 3.83e-11, 3.568e-11, 3.308e-11,
    3.047e-11, 2.82e-11, 2.594e-11, 2.409e-11, 2.237e-11, 2.065e-11,
    1.894e-11, 1.771e-11, 1.647e-11, 1.532e-11, 1.416e-11, 1.332e-11,
    1.246e-11, 1.161e-11, 1.087e-11, 1.017e-11, 9.471e-12, 8.853e-12,
    8.235e-12, 7.741e-12, 7.247e-12, 6.836e-12, 6.506e-12, 6.176e-12,
    5.913e-12, 5.65e-12, 5.419e-12, 5.221e-12, 5.024e-12, 4.859e-12,
    4.694e-12, 4.546e-12, 4.414e-12, 4.282e-12, 4.15e-12, 4.019e-12,
    3.903e-12, 3.805e-12, 3.706e-12, 3.607e-12, 3.508e-12, 3.41e-12,
    3.31e-12, 3.212e-12, 3.129e-12, 3.047e-12, 2.964e-12, 2.882e-12,
    2.8e-12, 2.734e-12, 2.668e-12, 2.602e-12, 2.537e-12, 2.471e-12,
    2.421e-12, 2.372e-12, 2.322e-12, 2.273e-12, 2.224e-12, 2.182e-12,
    2.141e-12, 2.1e-12, 2.059e-12, 2.018e-12, 1.977e-12, 1.935e-12,
    1.894e-12, 1.853e-12, 1.812e-12, 1.77e-12, 1.73e-12, 1.688e-12,
    1.647e-12, 1.606e-12, 1.565e-12, 1.524e-12, 1.483e-12, 1.441e-12,
    1.4e-12, 1.359e-12, 1.317e-12, 1.276e-12, 1.235e-12, 1.194e-12,
    1.153e-12, 1.112e-12, 1.071e-12, 1.029e-12, 9.883e-13
  };

  static double h2o[121] = {
    0.01166, 0.008269, 0.005742, 0.003845, 0.00277, 0.001897, 0.001272,
    0.000827, 0.000539, 0.0003469, 0.0001579, 3.134e-05, 1.341e-05,
    6.764e-06, 4.498e-06, 3.703e-06, 3.724e-06, 3.899e-06, 4.002e-06,
    4.122e-06, 4.277e-06, 4.438e-06, 4.558e-06, 4.673e-06, 4.763e-06,
    4.809e-06, 4.856e-06, 4.936e-06, 5.021e-06, 5.114e-06, 5.222e-06,
    5.331e-06, 5.414e-06, 5.488e-06, 5.563e-06, 5.633e-06, 5.704e-06,
    5.767e-06, 5.819e-06, 5.872e-06, 5.914e-06, 5.949e-06, 5.984e-06,
    6.015e-06, 6.044e-06, 6.073e-06, 6.104e-06, 6.136e-06, 6.167e-06,
    6.189e-06, 6.208e-06, 6.226e-06, 6.212e-06, 6.185e-06, 6.158e-06,
    6.114e-06, 6.066e-06, 6.018e-06, 5.877e-06, 5.728e-06, 5.582e-06,
    5.437e-06, 5.296e-06, 5.156e-06, 5.02e-06, 4.886e-06, 4.754e-06,
    4.625e-06, 4.498e-06, 4.374e-06, 4.242e-06, 4.096e-06, 3.955e-06,
    3.817e-06, 3.683e-06, 3.491e-06, 3.204e-06, 2.94e-06, 2.696e-06,
    2.47e-06, 2.252e-06, 2.019e-06, 1.808e-06, 1.618e-06, 1.445e-06,
    1.285e-06, 1.105e-06, 9.489e-07, 8.121e-07, 6.938e-07, 5.924e-07,
    5.04e-07, 4.288e-07, 3.648e-07, 3.103e-07, 2.642e-07, 2.252e-07,
    1.921e-07, 1.643e-07, 1.408e-07, 1.211e-07, 1.048e-07, 9.063e-08,
    7.835e-08, 6.774e-08, 5.936e-08, 5.221e-08, 4.592e-08, 4.061e-08,
    3.62e-08, 3.236e-08, 2.902e-08, 2.62e-08, 2.383e-08, 2.171e-08,
    1.989e-08, 1.823e-08, 1.684e-08, 1.562e-08, 1.449e-08, 1.351e-08
  };

  static double h2o2[121] = {
    1.779e-10, 7.938e-10, 8.953e-10, 8.032e-10, 6.564e-10, 5.159e-10,
    4.003e-10, 3.026e-10, 2.222e-10, 1.58e-10, 1.044e-10, 6.605e-11,
    3.413e-11, 1.453e-11, 1.062e-11, 1.009e-11, 9.597e-12, 1.175e-11,
    1.572e-11, 2.091e-11, 2.746e-11, 3.603e-11, 4.791e-11, 6.387e-11,
    8.239e-11, 1.007e-10, 1.23e-10, 1.363e-10, 1.489e-10, 1.585e-10,
    1.608e-10, 1.632e-10, 1.576e-10, 1.502e-10, 1.423e-10, 1.302e-10,
    1.192e-10, 1.085e-10, 9.795e-11, 8.854e-11, 8.057e-11, 7.36e-11,
    6.736e-11, 6.362e-11, 6.087e-11, 5.825e-11, 5.623e-11, 5.443e-11,
    5.27e-11, 5.098e-11, 4.931e-11, 4.769e-11, 4.611e-11, 4.458e-11,
    4.308e-11, 4.102e-11, 3.887e-11, 3.682e-11, 3.521e-11, 3.369e-11,
    3.224e-11, 3.082e-11, 2.946e-11, 2.814e-11, 2.687e-11, 2.566e-11,
    2.449e-11, 2.336e-11, 2.227e-11, 2.123e-11, 2.023e-11, 1.927e-11,
    1.835e-11, 1.746e-11, 1.661e-11, 1.58e-11, 1.502e-11, 1.428e-11,
    1.357e-11, 1.289e-11, 1.224e-11, 1.161e-11, 1.102e-11, 1.045e-11,
    9.895e-12, 9.369e-12, 8.866e-12, 8.386e-12, 7.922e-12, 7.479e-12,
    7.06e-12, 6.656e-12, 6.274e-12, 5.914e-12, 5.575e-12, 5.257e-12,
    4.959e-12, 4.679e-12, 4.42e-12, 4.178e-12, 3.954e-12, 3.75e-12,
    3.557e-12, 3.372e-12, 3.198e-12, 3.047e-12, 2.908e-12, 2.775e-12,
    2.653e-12, 2.544e-12, 2.442e-12, 2.346e-12, 2.26e-12, 2.183e-12,
    2.11e-12, 2.044e-12, 1.98e-12, 1.924e-12, 1.871e-12, 1.821e-12,
    1.775e-12
  };

  static double hcn[121] = {
    5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10,
    5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.498e-10, 5.495e-10, 5.493e-10,
    5.49e-10, 5.488e-10, 4.717e-10, 3.946e-10, 3.174e-10, 2.4e-10,
    1.626e-10, 1.619e-10, 1.612e-10, 1.602e-10, 1.593e-10, 1.582e-10,
    1.572e-10, 1.56e-10, 1.549e-10, 1.539e-10, 1.53e-10, 1.519e-10,
    1.506e-10, 1.487e-10, 1.467e-10, 1.449e-10, 1.43e-10, 1.413e-10,
    1.397e-10, 1.382e-10, 1.368e-10, 1.354e-10, 1.337e-10, 1.315e-10,
    1.292e-10, 1.267e-10, 1.241e-10, 1.215e-10, 1.19e-10, 1.165e-10,
    1.141e-10, 1.118e-10, 1.096e-10, 1.072e-10, 1.047e-10, 1.021e-10,
    9.968e-11, 9.739e-11, 9.539e-11, 9.339e-11, 9.135e-11, 8.898e-11,
    8.664e-11, 8.439e-11, 8.249e-11, 8.075e-11, 7.904e-11, 7.735e-11,
    7.565e-11, 7.399e-11, 7.245e-11, 7.109e-11, 6.982e-11, 6.863e-11,
    6.755e-11, 6.657e-11, 6.587e-11, 6.527e-11, 6.476e-11, 6.428e-11,
    6.382e-11, 6.343e-11, 6.307e-11, 6.272e-11, 6.238e-11, 6.205e-11,
    6.17e-11, 6.137e-11, 6.102e-11, 6.072e-11, 6.046e-11, 6.03e-11,
    6.018e-11, 6.01e-11, 6.001e-11, 5.992e-11, 5.984e-11, 5.975e-11,
    5.967e-11, 5.958e-11, 5.95e-11, 5.941e-11, 5.933e-11, 5.925e-11,
    5.916e-11, 5.908e-11, 5.899e-11, 5.891e-11, 5.883e-11, 5.874e-11,
  5.866e-11, 5.858e-11, 5.85e-11, 5.841e-11, 5.833e-11, 5.825e-11,
  5.817e-11, 5.808e-11, 5.8e-11, 5.792e-11, 5.784e-11
};

static double hno3[121] = {
  1.809e-10, 7.234e-10, 5.899e-10, 4.342e-10, 3.277e-10, 2.661e-10,
  2.35e-10, 2.267e-10, 2.389e-10, 2.651e-10, 3.255e-10, 4.099e-10,
  5.42e-10, 6.978e-10, 8.807e-10, 1.112e-09, 1.405e-09, 2.04e-09,
  3.111e-09, 4.5e-09, 5.762e-09, 7.37e-09, 7.852e-09, 8.109e-09,
  8.067e-09, 7.554e-09, 7.076e-09, 6.268e-09, 5.524e-09, 4.749e-09,
  3.909e-09, 3.223e-09, 2.517e-09, 1.942e-09, 1.493e-09, 1.122e-09,
  8.449e-10, 6.361e-10, 4.787e-10, 3.611e-10, 2.804e-10, 2.215e-10,
  1.758e-10, 1.441e-10, 1.197e-10, 9.953e-11, 8.505e-11, 7.334e-11,
  6.325e-11, 5.625e-11, 5.058e-11, 4.548e-11, 4.122e-11, 3.748e-11,
  3.402e-11, 3.088e-11, 2.8e-11, 2.536e-11, 2.293e-11, 2.072e-11,
  1.871e-11, 1.687e-11, 1.52e-11, 1.368e-11, 1.23e-11, 1.105e-11,
  9.922e-12, 8.898e-12, 7.972e-12, 7.139e-12, 6.385e-12, 5.708e-12,
  5.099e-12, 4.549e-12, 4.056e-12, 3.613e-12, 3.216e-12, 2.862e-12,
  2.544e-12, 2.259e-12, 2.004e-12, 1.776e-12, 1.572e-12, 1.391e-12,
  1.227e-12, 1.082e-12, 9.528e-13, 8.379e-13, 7.349e-13, 6.436e-13,
  5.634e-13, 4.917e-13, 4.291e-13, 3.745e-13, 3.267e-13, 2.854e-13,
  2.494e-13, 2.181e-13, 1.913e-13, 1.68e-13, 1.479e-13, 1.31e-13,
  1.159e-13, 1.025e-13, 9.067e-14, 8.113e-14, 7.281e-14, 6.535e-14,
  5.892e-14, 5.348e-14, 4.867e-14, 4.439e-14, 4.073e-14, 3.76e-14,
  3.476e-14, 3.229e-14, 3e-14, 2.807e-14, 2.635e-14, 2.473e-14,
  2.332e-14
};

static double hno4[121] = {
  6.118e-12, 3.594e-12, 2.807e-12, 3.04e-12, 4.458e-12, 7.986e-12,
  1.509e-11, 2.661e-11, 3.738e-11, 4.652e-11, 4.429e-11, 3.992e-11,
  3.347e-11, 3.005e-11, 3.173e-11, 4.055e-11, 5.812e-11, 8.489e-11,
  1.19e-10, 1.482e-10, 1.766e-10, 2.103e-10, 2.35e-10, 2.598e-10,
  2.801e-10, 2.899e-10, 3e-10, 2.817e-10, 2.617e-10, 2.332e-10,
  1.933e-10, 1.605e-10, 1.232e-10, 9.285e-11, 6.941e-11, 4.951e-11,
  3.539e-11, 2.402e-11, 1.522e-11, 9.676e-12, 6.056e-12, 3.745e-12,
  2.34e-12, 1.463e-12, 9.186e-13, 5.769e-13, 3.322e-13, 1.853e-13,
  1.035e-13, 7.173e-14, 5.382e-14, 4.036e-14, 3.401e-14, 2.997e-14,
  2.635e-14, 2.316e-14, 2.034e-14, 1.783e-14, 1.56e-14, 1.363e-14,
  1.19e-14, 1.037e-14, 9.032e-15, 7.846e-15, 6.813e-15, 5.912e-15,
  5.121e-15, 4.431e-15, 3.829e-15, 3.306e-15, 2.851e-15, 2.456e-15,
  2.114e-15, 1.816e-15, 1.559e-15, 1.337e-15, 1.146e-15, 9.811e-16,
  8.389e-16, 7.162e-16, 6.109e-16, 5.203e-16, 4.425e-16, 3.76e-16,
  3.184e-16, 2.692e-16, 2.274e-16, 1.917e-16, 1.61e-16, 1.35e-16,
  1.131e-16, 9.437e-17, 7.874e-17, 6.57e-17, 5.481e-17, 4.579e-17,
  3.828e-17, 3.204e-17, 2.691e-17, 2.264e-17, 1.912e-17, 1.626e-17,
  1.382e-17, 1.174e-17, 9.972e-18, 8.603e-18, 7.45e-18, 6.453e-18,
  5.623e-18, 4.944e-18, 4.361e-18, 3.859e-18, 3.443e-18, 3.096e-18,
  2.788e-18, 2.528e-18, 2.293e-18, 2.099e-18, 1.929e-18, 1.773e-18,
  1.64e-18
};

static double hocl[121] = {
  1.056e-12, 1.194e-12, 1.35e-12, 1.531e-12, 1.737e-12, 1.982e-12,
  2.263e-12, 2.599e-12, 2.991e-12, 3.459e-12, 4.012e-12, 4.662e-12,
  5.438e-12, 6.35e-12, 7.425e-12, 8.686e-12, 1.016e-11, 1.188e-11,
  1.389e-11, 1.659e-11, 2.087e-11, 2.621e-11, 3.265e-11, 4.064e-11,
  4.859e-11, 5.441e-11, 6.09e-11, 6.373e-11, 6.611e-11, 6.94e-11,
  7.44e-11, 7.97e-11, 8.775e-11, 9.722e-11, 1.064e-10, 1.089e-10,
  1.114e-10, 1.106e-10, 1.053e-10, 1.004e-10, 9.006e-11, 7.778e-11,
  6.739e-11, 5.636e-11, 4.655e-11, 3.845e-11, 3.042e-11, 2.368e-11,
  1.845e-11, 1.442e-11, 1.127e-11, 8.814e-12, 6.544e-12, 4.763e-12,
  3.449e-12, 2.612e-12, 1.999e-12, 1.526e-12, 1.16e-12, 8.793e-13,
  6.655e-13, 5.017e-13, 3.778e-13, 2.829e-13, 2.117e-13, 1.582e-13,
  1.178e-13, 8.755e-14, 6.486e-14, 4.799e-14, 3.54e-14, 2.606e-14,
  1.916e-14, 1.403e-14, 1.026e-14, 7.48e-15, 5.446e-15, 3.961e-15,
  2.872e-15, 2.076e-15, 1.498e-15, 1.077e-15, 7.726e-16, 5.528e-16,
  3.929e-16, 2.785e-16, 1.969e-16, 1.386e-16, 9.69e-17, 6.747e-17,
  4.692e-17, 3.236e-17, 2.232e-17, 1.539e-17, 1.061e-17, 7.332e-18,
  5.076e-18, 3.522e-18, 2.461e-18, 1.726e-18, 1.22e-18, 8.75e-19,
  6.264e-19, 4.482e-19, 3.207e-19, 2.368e-19, 1.762e-19, 1.312e-19,
  9.891e-20, 7.595e-20, 5.87e-20, 4.567e-20, 3.612e-20, 2.904e-20,
  2.343e-20, 1.917e-20, 1.568e-20, 1.308e-20, 1.1e-20, 9.25e-21,
  7.881e-21
};

static double n2o[121] = {
  3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07,
  3.17e-07, 3.17e-07, 3.17e-07, 3.124e-07, 3.077e-07, 3.03e-07,
  2.984e-07, 2.938e-07, 2.892e-07, 2.847e-07, 2.779e-07, 2.705e-07,
  2.631e-07, 2.557e-07, 2.484e-07, 2.345e-07, 2.201e-07, 2.01e-07,
  1.754e-07, 1.532e-07, 1.329e-07, 1.154e-07, 1.003e-07, 8.735e-08,
  7.617e-08, 6.512e-08, 5.547e-08, 4.709e-08, 3.915e-08, 3.259e-08,
  2.738e-08, 2.327e-08, 1.98e-08, 1.711e-08, 1.493e-08, 1.306e-08,
  1.165e-08, 1.049e-08, 9.439e-09, 8.375e-09, 7.391e-09, 6.525e-09,
  5.759e-09, 5.083e-09, 4.485e-09, 3.953e-09, 3.601e-09, 3.27e-09,
  2.975e-09, 2.757e-09, 2.556e-09, 2.37e-09, 2.195e-09, 2.032e-09,
  1.912e-09, 1.79e-09, 1.679e-09, 1.572e-09, 1.482e-09, 1.402e-09,
  1.326e-09, 1.254e-09, 1.187e-09, 1.127e-09, 1.071e-09, 1.02e-09,
  9.673e-10, 9.193e-10, 8.752e-10, 8.379e-10, 8.017e-10, 7.66e-10,
  7.319e-10, 7.004e-10, 6.721e-10, 6.459e-10, 6.199e-10, 5.942e-10,
  5.703e-10, 5.488e-10, 5.283e-10, 5.082e-10, 4.877e-10, 4.696e-10,
  4.52e-10, 4.355e-10, 4.198e-10, 4.039e-10, 3.888e-10, 3.754e-10,
  3.624e-10, 3.499e-10, 3.381e-10, 3.267e-10, 3.163e-10, 3.058e-10,
  2.959e-10, 2.864e-10, 2.77e-10, 2.686e-10, 2.604e-10, 2.534e-10,
  2.462e-10, 2.386e-10, 2.318e-10, 2.247e-10, 2.189e-10, 2.133e-10,
  2.071e-10, 2.014e-10, 1.955e-10, 1.908e-10, 1.86e-10, 1.817e-10
};

static double n2o5[121] = {
  1.231e-11, 3.035e-12, 1.702e-12, 9.877e-13, 8.081e-13, 9.039e-13,
  1.169e-12, 1.474e-12, 1.651e-12, 1.795e-12, 1.998e-12, 2.543e-12,
  4.398e-12, 7.698e-12, 1.28e-11, 2.131e-11, 3.548e-11, 5.894e-11,
  7.645e-11, 1.089e-10, 1.391e-10, 1.886e-10, 2.386e-10, 2.986e-10,
  3.487e-10, 3.994e-10, 4.5e-10, 4.6e-10, 4.591e-10, 4.1e-10, 3.488e-10,
  2.846e-10, 2.287e-10, 1.696e-10, 1.011e-10, 6.428e-11, 4.324e-11,
  2.225e-11, 6.214e-12, 3.608e-12, 8.793e-13, 4.491e-13, 1.04e-13,
  6.1e-14, 3.436e-14, 6.671e-15, 1.171e-15, 5.848e-16, 1.212e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16
};

static double nh3[121] = {
  1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
  1e-10, 1e-10, 1e-10, 1e-10, 9.444e-11, 8.488e-11, 7.241e-11, 5.785e-11,
  4.178e-11, 3.018e-11, 2.18e-11, 1.574e-11, 1.137e-11, 8.211e-12,
  5.973e-12, 4.327e-12, 3.118e-12, 2.234e-12, 1.573e-12, 1.04e-12,
  6.762e-13, 4.202e-13, 2.406e-13, 1.335e-13, 6.938e-14, 3.105e-14,
  1.609e-14, 1.033e-14, 6.432e-15, 4.031e-15, 2.555e-15, 1.656e-15,
  1.115e-15, 7.904e-16, 5.63e-16, 4.048e-16, 2.876e-16, 2.004e-16,
  1.356e-16, 9.237e-17, 6.235e-17, 4.223e-17, 3.009e-17, 2.328e-17,
  2.002e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17
};

static double no[121] = {
  2.586e-10, 4.143e-11, 1.566e-11, 9.591e-12, 8.088e-12, 8.462e-12,
  1.013e-11, 1.328e-11, 1.855e-11, 2.678e-11, 3.926e-11, 5.464e-11,
  7.012e-11, 8.912e-11, 1.127e-10, 1.347e-10, 1.498e-10, 1.544e-10,
  1.602e-10, 1.824e-10, 2.078e-10, 2.366e-10, 2.691e-10, 5.141e-10,
  8.259e-10, 1.254e-09, 1.849e-09, 2.473e-09, 3.294e-09, 4.16e-09,
  5.095e-09, 6.11e-09, 6.93e-09, 7.888e-09, 8.903e-09, 9.713e-09,
  1.052e-08, 1.115e-08, 1.173e-08, 1.21e-08, 1.228e-08, 1.239e-08,
  1.231e-08, 1.213e-08, 1.192e-08, 1.138e-08, 1.085e-08, 1.008e-08,
  9.224e-09, 8.389e-09, 7.262e-09, 6.278e-09, 5.335e-09, 4.388e-09,
  3.589e-09, 2.761e-09, 2.129e-09, 1.633e-09, 1.243e-09, 9.681e-10,
  8.355e-10, 7.665e-10, 7.442e-10, 8.584e-10, 9.732e-10, 1.063e-09,
  1.163e-09, 1.286e-09, 1.472e-09, 1.707e-09, 2.032e-09, 2.474e-09,
  2.977e-09, 3.506e-09, 4.102e-09, 5.013e-09, 6.493e-09, 8.414e-09,
  1.077e-08, 1.367e-08, 1.777e-08, 2.625e-08, 3.926e-08, 5.545e-08,
  7.195e-08, 9.464e-08, 1.404e-07, 2.183e-07, 3.329e-07, 4.535e-07,
  6.158e-07, 8.187e-07, 1.075e-06, 1.422e-06, 1.979e-06, 2.71e-06,
  3.58e-06, 4.573e-06, 5.951e-06, 7.999e-06, 1.072e-05, 1.372e-05,
  1.697e-05, 2.112e-05, 2.643e-05, 3.288e-05, 3.994e-05, 4.794e-05,
  5.606e-05, 6.383e-05, 7.286e-05, 8.156e-05, 8.883e-05, 9.469e-05,
  9.848e-05, 0.0001023, 0.0001066, 0.0001115, 0.0001145, 0.0001142,
  0.0001133
};

static double no2[121] = {
  3.036e-09, 2.945e-10, 9.982e-11, 5.069e-11, 3.485e-11, 2.982e-11,
  2.947e-11, 3.164e-11, 3.714e-11, 4.586e-11, 6.164e-11, 8.041e-11,
  9.982e-11, 1.283e-10, 1.73e-10, 2.56e-10, 3.909e-10, 5.959e-10,
  9.081e-10, 1.384e-09, 1.788e-09, 2.189e-09, 2.686e-09, 3.091e-09,
  3.49e-09, 3.796e-09, 4.2e-09, 5.103e-09, 6.005e-09, 6.3e-09, 6.706e-09,
  7.07e-09, 7.434e-09, 7.663e-09, 7.788e-09, 7.8e-09, 7.597e-09,
  7.482e-09, 7.227e-09, 6.403e-09, 5.585e-09, 4.606e-09, 3.703e-09,
  2.984e-09, 2.183e-09, 1.48e-09, 8.441e-10, 5.994e-10, 3.799e-10,
  2.751e-10, 1.927e-10, 1.507e-10, 1.102e-10, 6.971e-11, 5.839e-11,
  3.904e-11, 3.087e-11, 2.176e-11, 1.464e-11, 1.209e-11, 8.497e-12,
  6.477e-12, 4.371e-12, 2.914e-12, 2.424e-12, 1.753e-12, 1.35e-12,
  9.417e-13, 6.622e-13, 5.148e-13, 3.841e-13, 3.446e-13, 3.01e-13,
  2.551e-13, 2.151e-13, 1.829e-13, 1.64e-13, 1.475e-13, 1.352e-13,
  1.155e-13, 9.963e-14, 9.771e-14, 9.577e-14, 9.384e-14, 9.186e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14
};

static double o3[121] = {
  2.218e-08, 3.394e-08, 3.869e-08, 4.219e-08, 4.501e-08, 4.778e-08,
  5.067e-08, 5.402e-08, 5.872e-08, 6.521e-08, 7.709e-08, 9.461e-08,
  1.269e-07, 1.853e-07, 2.723e-07, 3.964e-07, 5.773e-07, 8.2e-07,
  1.155e-06, 1.59e-06, 2.076e-06, 2.706e-06, 3.249e-06, 3.848e-06,
  4.459e-06, 4.986e-06, 5.573e-06, 5.958e-06, 6.328e-06, 6.661e-06,
  6.9e-06, 7.146e-06, 7.276e-06, 7.374e-06, 7.447e-06, 7.383e-06,
  7.321e-06, 7.161e-06, 6.879e-06, 6.611e-06, 6.216e-06, 5.765e-06,
  5.355e-06, 4.905e-06, 4.471e-06, 4.075e-06, 3.728e-06, 3.413e-06,
  3.125e-06, 2.856e-06, 2.607e-06, 2.379e-06, 2.17e-06, 1.978e-06,
  1.8e-06, 1.646e-06, 1.506e-06, 1.376e-06, 1.233e-06, 1.102e-06,
  9.839e-07, 8.771e-07, 7.814e-07, 6.947e-07, 6.102e-07, 5.228e-07,
  4.509e-07, 3.922e-07, 3.501e-07, 3.183e-07, 2.909e-07, 2.686e-07,
  2.476e-07, 2.284e-07, 2.109e-07, 2.003e-07, 2.013e-07, 2.022e-07,
  2.032e-07, 2.042e-07, 2.097e-07, 2.361e-07, 2.656e-07, 2.989e-07,
  3.37e-07, 3.826e-07, 4.489e-07, 5.26e-07, 6.189e-07, 7.312e-07,
  8.496e-07, 8.444e-07, 8.392e-07, 8.339e-07, 8.286e-07, 8.234e-07,
  8.181e-07, 8.129e-07, 8.077e-07, 8.026e-07, 6.918e-07, 5.176e-07,
  3.865e-07, 2.885e-07, 2.156e-07, 1.619e-07, 1.219e-07, 9.161e-08,
  6.972e-08, 5.399e-08, 3.498e-08, 2.111e-08, 1.322e-08, 8.482e-09,
  5.527e-09, 3.423e-09, 2.071e-09, 1.314e-09, 8.529e-10, 5.503e-10,
  3.665e-10
};

static double ocs[121] = {
  6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 5.997e-10,
  5.989e-10, 5.881e-10, 5.765e-10, 5.433e-10, 5.074e-10, 4.567e-10,
  4.067e-10, 3.601e-10, 3.093e-10, 2.619e-10, 2.232e-10, 1.805e-10,
  1.46e-10, 1.187e-10, 8.03e-11, 5.435e-11, 3.686e-11, 2.217e-11,
  1.341e-11, 8.756e-12, 4.511e-12, 2.37e-12, 1.264e-12, 8.28e-13,
  5.263e-13, 3.209e-13, 1.717e-13, 9.068e-14, 4.709e-14, 2.389e-14,
  1.236e-14, 1.127e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14
};

static double sf6[121] = {
  4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12,
  4.103e-12, 4.103e-12, 4.103e-12, 4.087e-12, 4.064e-12, 4.023e-12,
  3.988e-12, 3.941e-12, 3.884e-12, 3.755e-12, 3.622e-12, 3.484e-12,
  3.32e-12, 3.144e-12, 2.978e-12, 2.811e-12, 2.653e-12, 2.489e-12,
  2.332e-12, 2.199e-12, 2.089e-12, 2.013e-12, 1.953e-12, 1.898e-12,
  1.859e-12, 1.826e-12, 1.798e-12, 1.776e-12, 1.757e-12, 1.742e-12,
  1.728e-12, 1.717e-12, 1.707e-12, 1.698e-12, 1.691e-12, 1.685e-12,
  1.679e-12, 1.675e-12, 1.671e-12, 1.668e-12, 1.665e-12, 1.663e-12,
  1.661e-12, 1.659e-12, 1.658e-12, 1.657e-12, 1.656e-12, 1.655e-12,
  1.654e-12, 1.653e-12, 1.653e-12, 1.652e-12, 1.652e-12, 1.652e-12,
  1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12,
  1.651e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12
};

static double so2[121] = {
  1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
  1e-10, 1e-10, 9.867e-11, 9.537e-11, 9e-11, 8.404e-11, 7.799e-11,
  7.205e-11, 6.616e-11, 6.036e-11, 5.475e-11, 5.007e-11, 4.638e-11,
  4.346e-11, 4.055e-11, 3.763e-11, 3.471e-11, 3.186e-11, 2.905e-11,
  2.631e-11, 2.358e-11, 2.415e-11, 2.949e-11, 3.952e-11, 5.155e-11,
    6.76e-11, 8.741e-11, 1.099e-10, 1.278e-10, 1.414e-10, 1.512e-10,
    1.607e-10, 1.699e-10, 1.774e-10, 1.832e-10, 1.871e-10, 1.907e-10,
    1.943e-10, 1.974e-10, 1.993e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
    2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10
  };

  static int ig_co2 = -999;

  double co2, *q[NG] = { NULL };

  int ig, ip, iw, iz;

  /* Find emitter index of CO2... */
  if (ig_co2 == -999)
    ig_co2 = find_emitter(ctl, "CO2");

  /* Identify variable... */
  for (ig = 0; ig < ctl->ng; ig++) {
    q[ig] = NULL;
    if (strcasecmp(ctl->emitter[ig], "C2H2") == 0)
      q[ig] = c2h2;
    if (strcasecmp(ctl->emitter[ig], "C2H6") == 0)
      q[ig] = c2h6;
    if (strcasecmp(ctl->emitter[ig], "CCl4") == 0)
      q[ig] = ccl4;
    if (strcasecmp(ctl->emitter[ig], "CH4") == 0)
      q[ig] = ch4;
    if (strcasecmp(ctl->emitter[ig], "ClO") == 0)
      q[ig] = clo;
    if (strcasecmp(ctl->emitter[ig], "ClONO2") == 0)
      q[ig] = clono2;
    if (strcasecmp(ctl->emitter[ig], "CO") == 0)
      q[ig] = co;
    if (strcasecmp(ctl->emitter[ig], "COF2") == 0)
      q[ig] = cof2;
    if (strcasecmp(ctl->emitter[ig], "F11") == 0)
      q[ig] = f11;
    if (strcasecmp(ctl->emitter[ig], "F12") == 0)
      q[ig] = f12;
    if (strcasecmp(ctl->emitter[ig], "F14") == 0)
      q[ig] = f14;
    if (strcasecmp(ctl->emitter[ig], "F22") == 0)
      q[ig] = f22;
    if (strcasecmp(ctl->emitter[ig], "H2O") == 0)
      q[ig] = h2o;
    if (strcasecmp(ctl->emitter[ig], "H2O2") == 0)
      q[ig] = h2o2;
    if (strcasecmp(ctl->emitter[ig], "HCN") == 0)
      q[ig] = hcn;
    if (strcasecmp(ctl->emitter[ig], "HNO3") == 0)
      q[ig] = hno3;
    if (strcasecmp(ctl->emitter[ig], "HNO4") == 0)
      q[ig] = hno4;
    if (strcasecmp(ctl->emitter[ig], "HOCl") == 0)
      q[ig] = hocl;
    if (strcasecmp(ctl->emitter[ig], "N2O") == 0)
      q[ig] = n2o;
    if (strcasecmp(ctl->emitter[ig], "N2O5") == 0)
      q[ig] = n2o5;
    if (strcasecmp(ctl->emitter[ig], "NH3") == 0)
      q[ig] = nh3;
    if (strcasecmp(ctl->emitter[ig], "NO") == 0)
      q[ig] = no;
    if (strcasecmp(ctl->emitter[ig], "NO2") == 0)
      q[ig] = no2;
    if (strcasecmp(ctl->emitter[ig], "O3") == 0)
      q[ig] = o3;
    if (strcasecmp(ctl->emitter[ig], "OCS") == 0)
      q[ig] = ocs;
    if (strcasecmp(ctl->emitter[ig], "SF6") == 0)
      q[ig] = sf6;
    if (strcasecmp(ctl->emitter[ig], "SO2") == 0)
      q[ig] = so2;
  }

  /* Loop over atmospheric data points... */
  for (ip = 0; ip < atm->np; ip++) {

    /* Get altitude index... */
    iz = locate(z, 121, atm->z[ip]);

    /* Interpolate pressure... */
    atm->p[ip] = EXP(z[iz], pre[iz], z[iz + 1], pre[iz + 1], atm->z[ip]);

    /* Interpolate temperature... */
    atm->t[ip] = LIN(z[iz], tem[iz], z[iz + 1], tem[iz + 1], atm->z[ip]);

    /* Interpolate trace gases... */
    for (ig = 0; ig < ctl->ng; ig++)
      if (q[ig] != NULL)
        atm->q[ig][ip] =
          LIN(z[iz], q[ig][iz], z[iz + 1], q[ig][iz + 1], atm->z[ip]);
      else
        atm->q[ig][ip] = 0;

    /* Set CO2... */
    if (ig_co2 >= 0) {
      co2 =
        371.789948e-6 + 2.026214e-6 * (atm->time[ip] - 63158400.) / 31557600.;
      atm->q[ig_co2][ip] = co2;
    }

    /* Set extinction to zero... */
    for (iw = 0; iw < ctl->nw; iw++)
      atm->k[iw][ip] = 0;
  }
}

/*****************************************************************************/

double ctmco2(
  double nu,
  double p,
  double t,
  double u) {

  static double co2296[2001] = { 9.3388e-5, 9.7711e-5, 1.0224e-4, 1.0697e-4,
    1.1193e-4, 1.1712e-4, 1.2255e-4, 1.2824e-4, 1.3419e-4, 1.4043e-4,
    1.4695e-4, 1.5378e-4, 1.6094e-4, 1.6842e-4, 1.7626e-4, 1.8447e-4,
    1.9307e-4, 2.0207e-4, 2.1149e-4, 2.2136e-4, 2.3169e-4, 2.4251e-4,
    2.5384e-4, 2.657e-4, 2.7813e-4, 2.9114e-4, 3.0477e-4, 3.1904e-4,
    3.3399e-4, 3.4965e-4, 3.6604e-4, 3.8322e-4, 4.0121e-4, 4.2006e-4,
    4.398e-4, 4.6047e-4, 4.8214e-4, 5.0483e-4, 5.286e-4, 5.535e-4,
    5.7959e-4, 6.0693e-4, 6.3557e-4, 6.6558e-4, 6.9702e-4, 7.2996e-4,
    7.6449e-4, 8.0066e-4, 8.3856e-4, 8.7829e-4, 9.1991e-4, 9.6354e-4,
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    .0054567, .0057219, .0060002, .0062923, .0065988, .0069204,
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    .074975, .078807, .082839, .087082, .091549, .096249, .1012,
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    .15935, .16765, .17639, .18561, .19531, .20554, .21632, .22769,
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    7.845, 7.2868, 6.7704, 6.2927, 5.8508, 5.4421, 5.064, 4.714,
    4.3902, 4.0902, 3.8121, 3.5543, 3.315, 3.093, 2.8869, 2.6953,
    2.5172, 2.3517, 2.1977, 2.0544, 1.9211, 1.7969, 1.6812, 1.5735,
    1.4731, 1.3794, 1.2921, 1.2107, 1.1346, 1.0637, .99744, .93554,
    .87771, .82368, .77313, .72587, .6816, .64014, .60134, .565,
    .53086, .49883, .46881, .44074, .4144, .38979, .36679, .34513,
    .32474, .30552, .28751, .27045, .25458, .23976, .22584, .21278,
    .20051, .18899, .17815, .16801, .15846, .14954, .14117, .13328,
    .12584
  };

  double xw, dw, ew, cw296, cw260, cw230, dt230, dt260, dt296, ctw, ctmpth;

  int iw, jw;

  /* Get CO2 continuum absorption... */
  xw = nu / 2 + 1;
  if (xw >= 1 && xw < 2001) {
    iw = (int) xw;
    jw = iw + 1;
    dw = xw - iw;
    ew = 1 - dw;
    cw296 = ew * co2296[iw - 1] + dw * co2296[jw - 1];
    cw260 = ew * co2260[iw - 1] + dw * co2260[jw - 1];
    cw230 = ew * co2230[iw - 1] + dw * co2230[jw - 1];
    dt230 = t - 230;
    dt260 = t - 260;
    dt296 = t - 296;
    ctw = dt260 * 5.050505e-4 * dt296 * cw230 - dt230 * 9.259259e-4
      * dt296 * cw260 + dt230 * 4.208754e-4 * dt260 * cw296;
    ctmpth = u / GSL_CONST_NUM_AVOGADRO / 1000 * p / P0 * ctw;
  } else
    ctmpth = 0;
  return ctmpth;
}

/*****************************************************************************/

double ctmh2o(
  double nu,
  double p,
  double t,
  double q,
  double u) {

  static double h2o296[2001] = { .17, .1695, .172, .168, .1687, .1624, .1606,
    .1508, .1447, .1344, .1214, .1133, .1009, .09217, .08297, .06989,
    .06513, .05469, .05056, .04417, .03779, .03484, .02994, .0272,
    .02325, .02063, .01818, .01592, .01405, .01251, .0108, .009647,
    .008424, .007519, .006555, .00588, .005136, .004511, .003989,
    .003509, .003114, .00274, .002446, .002144, .001895, .001676,
    .001486, .001312, .001164, .001031, 9.129e-4, 8.106e-4, 7.213e-4,
    6.4e-4, 5.687e-4, 5.063e-4, 4.511e-4, 4.029e-4, 3.596e-4,
    3.22e-4, 2.889e-4, 2.597e-4, 2.337e-4, 2.108e-4, 1.907e-4,
    1.728e-4, 1.57e-4, 1.43e-4, 1.305e-4, 1.195e-4, 1.097e-4,
    1.009e-4, 9.307e-5, 8.604e-5, 7.971e-5, 7.407e-5, 6.896e-5,
    6.433e-5, 6.013e-5, 5.631e-5, 5.283e-5, 4.963e-5, 4.669e-5,
    4.398e-5, 4.148e-5, 3.917e-5, 3.702e-5, 3.502e-5, 3.316e-5,
    3.142e-5, 2.978e-5, 2.825e-5, 2.681e-5, 2.546e-5, 2.419e-5,
    2.299e-5, 2.186e-5, 2.079e-5, 1.979e-5, 1.884e-5, 1.795e-5,
    1.711e-5, 1.633e-5, 1.559e-5, 1.49e-5, 1.426e-5, 1.367e-5,
    1.312e-5, 1.263e-5, 1.218e-5, 1.178e-5, 1.143e-5, 1.112e-5,
    1.088e-5, 1.07e-5, 1.057e-5, 1.05e-5, 1.051e-5, 1.059e-5,
    1.076e-5, 1.1e-5, 1.133e-5, 1.18e-5, 1.237e-5, 1.308e-5,
    1.393e-5, 1.483e-5, 1.614e-5, 1.758e-5, 1.93e-5, 2.123e-5,
    2.346e-5, 2.647e-5, 2.93e-5, 3.279e-5, 3.745e-5, 4.152e-5,
    4.813e-5, 5.477e-5, 6.203e-5, 7.331e-5, 8.056e-5, 9.882e-5,
    1.05e-4, 1.21e-4, 1.341e-4, 1.572e-4, 1.698e-4, 1.968e-4,
    2.175e-4, 2.431e-4, 2.735e-4, 2.867e-4, 3.19e-4, 3.371e-4,
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    3.841e-4, 3.852e-4, 3.815e-4, 3.762e-4, 3.618e-4, 3.579e-4,
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    1.011e-4, 9.237e-5, 7.909e-5, 7.006e-5, 6.112e-5, 5.401e-5,
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1.978e-13, 2.194e-13, 2.388e-13, 2.489e-13, 2.626e-13, 2.865e-13,
3.105e-13, 3.387e-13, 3.652e-13, 3.984e-13, 4.398e-13, 4.906e-13,
5.55e-13, 6.517e-13, 7.813e-13, 9.272e-13, 1.164e-12, 1.434e-12,
1.849e-12, 2.524e-12, 3.328e-12, 4.523e-12, 6.108e-12, 8.207e-12,
1.122e-11, 1.477e-11, 1.9e-11, 2.412e-11, 2.984e-11, 3.68e-11,
4.353e-11, 4.963e-11, 5.478e-11, 5.903e-11, 6.233e-11, 6.483e-11,
6.904e-11, 7.569e-11, 8.719e-11, 1.048e-10, 1.278e-10, 1.557e-10,
1.869e-10, 2.218e-10, 2.61e-10, 2.975e-10, 3.371e-10, 3.746e-10,
4.065e-10, 4.336e-10, 4.503e-10, 4.701e-10, 4.8e-10, 4.917e-10,
5.038e-10, 5.128e-10, 5.143e-10, 5.071e-10, 5.019e-10, 5.025e-10,
5.183e-10, 5.496e-10, 5.877e-10, 6.235e-10, 6.42e-10, 6.234e-10,
5.698e-10, 4.916e-10, 4.022e-10, 3.126e-10, 2.282e-10, 1.639e-10,
1.142e-10, 7.919e-11, 5.69e-11, 4.313e-11, 3.413e-11, 2.807e-11,
2.41e-11, 2.166e-11, 2.024e-11, 1.946e-11, 1.929e-11, 1.963e-11,
2.035e-11, 2.162e-11, 2.305e-11, 2.493e-11, 2.748e-11, 3.048e-11,
3.413e-11, 3.754e-11, 4.155e-11, 4.635e-11, 5.11e-11, 5.734e-11,
6.338e-11, 6.99e-11, 7.611e-11, 8.125e-11, 8.654e-11, 8.951e-11,
9.182e-11, 9.31e-11, 9.273e-11, 9.094e-11, 8.849e-11, 8.662e-11,
8.67e-11, 8.972e-11, 9.566e-11, 1.025e-10, 1.083e-10, 1.111e-10,
1.074e-10, 9.771e-11, 8.468e-11, 6.958e-11, 5.47e-11, 4.04e-11,
2.94e-11, 2.075e-11, 1.442e-11, 1.01e-11, 7.281e-12, 5.409e-12,
4.138e-12, 3.304e-12, 2.784e-12, 2.473e-12, 2.273e-12, 2.186e-12,
2.118e-12, 2.066e-12, 1.958e-12, 1.818e-12, 1.675e-12, 1.509e-12,
1.349e-12, 1.171e-12, 9.838e-13, 8.213e-13, 6.765e-13, 5.378e-13,
4.161e-13, 3.119e-13, 2.279e-13, 1.637e-13, 1.152e-13, 8.112e-14,
5.919e-14, 4.47e-14, 3.492e-14, 2.811e-14, 2.319e-14, 1.948e-14,
1.66e-14, 1.432e-14, 1.251e-14, 1.109e-14, 1.006e-14, 9.45e-15,
9.384e-15, 1.012e-14, 1.216e-14, 1.636e-14, 2.305e-14, 3.488e-14,
5.572e-14, 8.479e-14, 1.265e-13, 1.905e-13, 2.73e-13, 3.809e-13,
4.955e-13, 6.303e-13, 7.861e-13, 9.427e-13, 1.097e-12, 1.212e-12,
1.328e-12, 1.415e-12, 1.463e-12, 1.495e-12, 1.571e-12, 1.731e-12,
1.981e-12, 2.387e-12, 2.93e-12, 3.642e-12, 4.584e-12, 5.822e-12,
7.278e-12, 9.193e-12, 1.135e-11, 1.382e-11, 1.662e-11, 1.958e-11,
2.286e-11, 2.559e-11, 2.805e-11, 2.988e-11, 3.106e-11, 3.182e-11,
3.2e-11, 3.258e-11, 3.362e-11, 3.558e-11, 3.688e-11, 3.8e-11,
3.929e-11, 4.062e-11, 4.186e-11, 4.293e-11, 4.48e-11, 4.643e-11,
4.704e-11, 4.571e-11, 4.206e-11, 3.715e-11, 3.131e-11, 2.541e-11,
1.978e-11, 1.508e-11, 1.146e-11, 8.7e-12, 6.603e-12, 5.162e-12,
4.157e-12, 3.408e-12, 2.829e-12, 2.405e-12, 2.071e-12, 1.826e-12,
    1.648e-12, 1.542e-12, 1.489e-12, 1.485e-12, 1.493e-12, 1.545e-12,
    1.637e-12, 1.814e-12, 2.061e-12, 2.312e-12, 2.651e-12, 3.03e-12,
    3.46e-12, 3.901e-12, 4.306e-12, 4.721e-12, 5.008e-12, 5.281e-12,
    5.541e-12, 5.791e-12, 6.115e-12, 6.442e-12, 6.68e-12, 6.791e-12,
    6.831e-12, 6.839e-12, 6.946e-12, 7.128e-12, 7.537e-12, 8.036e-12,
    8.392e-12, 8.526e-12, 8.11e-12, 7.325e-12, 6.329e-12, 5.183e-12,
    4.081e-12, 2.985e-12, 2.141e-12, 1.492e-12, 1.015e-12, 6.684e-13,
    4.414e-13, 2.987e-13, 2.038e-13, 1.391e-13, 9.86e-14, 7.24e-14,
    5.493e-14, 4.288e-14, 3.427e-14, 2.787e-14, 2.296e-14, 1.909e-14,
    1.598e-14, 1.344e-14, 1.135e-14, 9.616e-15, 8.169e-15, 6.957e-15,
    5.938e-15, 5.08e-15, 4.353e-15, 3.738e-15, 3.217e-15, 2.773e-15,
    2.397e-15, 2.077e-15, 1.805e-15, 1.575e-15, 1.382e-15, 1.221e-15,
    1.09e-15, 9.855e-16, 9.068e-16, 8.537e-16, 8.27e-16, 8.29e-16,
    8.634e-16, 9.359e-16, 1.055e-15, 1.233e-15, 1.486e-15, 1.839e-15,
    2.326e-15, 2.998e-15, 3.934e-15, 5.256e-15, 7.164e-15, 9.984e-15,
    1.427e-14, 2.099e-14, 3.196e-14, 5.121e-14, 7.908e-14, 1.131e-13,
    1.602e-13, 2.239e-13, 3.075e-13, 4.134e-13, 5.749e-13, 7.886e-13,
    1.071e-12, 1.464e-12, 2.032e-12, 2.8e-12, 3.732e-12, 4.996e-12,
    6.483e-12, 8.143e-12, 1.006e-11, 1.238e-11, 1.484e-11, 1.744e-11,
    2.02e-11, 2.274e-11, 2.562e-11, 2.848e-11, 3.191e-11, 3.617e-11,
    4.081e-11, 4.577e-11, 4.937e-11, 5.204e-11, 5.401e-11, 5.462e-11,
    5.507e-11, 5.51e-11, 5.605e-11, 5.686e-11, 5.739e-11, 5.766e-11,
    5.74e-11, 5.754e-11, 5.761e-11, 5.777e-11, 5.712e-11, 5.51e-11,
    5.088e-11, 4.438e-11, 3.728e-11, 2.994e-11, 2.305e-11, 1.715e-11,
    1.256e-11, 9.208e-12, 6.745e-12, 5.014e-12, 3.785e-12, 2.9e-12,
    2.239e-12, 1.757e-12, 1.414e-12, 1.142e-12, 9.482e-13, 8.01e-13,
    6.961e-13, 6.253e-13, 5.735e-13, 5.433e-13, 5.352e-13, 5.493e-13,
    5.706e-13, 6.068e-13, 6.531e-13, 7.109e-13, 7.767e-13, 8.59e-13,
    9.792e-13, 1.142e-12, 1.371e-12, 1.65e-12, 1.957e-12, 2.302e-12,
    2.705e-12, 3.145e-12, 3.608e-12, 4.071e-12, 4.602e-12, 5.133e-12,
    5.572e-12, 5.987e-12, 6.248e-12, 6.533e-12, 6.757e-12, 6.935e-12,
    7.224e-12, 7.422e-12, 7.538e-12, 7.547e-12, 7.495e-12, 7.543e-12,
    7.725e-12, 8.139e-12, 8.627e-12, 9.146e-12, 9.443e-12, 9.318e-12,
    8.649e-12, 7.512e-12, 6.261e-12, 4.915e-12, 3.647e-12, 2.597e-12,
    1.785e-12, 1.242e-12, 8.66e-13, 6.207e-13, 4.61e-13, 3.444e-13,
    2.634e-13, 2.1e-13, 1.725e-13, 1.455e-13, 1.237e-13, 1.085e-13,
    9.513e-14, 7.978e-14, 6.603e-14, 5.288e-14, 4.084e-14, 2.952e-14,
    2.157e-14, 1.593e-14, 1.199e-14, 9.267e-15, 7.365e-15, 6.004e-15,
    4.995e-15, 4.218e-15, 3.601e-15, 3.101e-15, 2.692e-15, 2.36e-15,
    2.094e-15, 1.891e-15, 1.755e-15, 1.699e-15, 1.755e-15, 1.987e-15,
    2.506e-15, 3.506e-15, 5.289e-15, 8.311e-15, 1.325e-14, 2.129e-14,
    3.237e-14, 4.595e-14, 6.441e-14, 8.433e-14, 1.074e-13, 1.383e-13,
    1.762e-13, 2.281e-13, 2.831e-13, 3.523e-13, 4.38e-13, 5.304e-13,
    6.29e-13, 7.142e-13, 8.032e-13, 8.934e-13, 9.888e-13, 1.109e-12,
    1.261e-12, 1.462e-12, 1.74e-12, 2.099e-12, 2.535e-12, 3.008e-12,
    3.462e-12, 3.856e-12, 4.098e-12, 4.239e-12, 4.234e-12, 4.132e-12,
    3.986e-12, 3.866e-12, 3.829e-12, 3.742e-12, 3.705e-12, 3.694e-12,
    3.765e-12, 3.849e-12, 3.929e-12, 4.056e-12, 4.092e-12, 4.047e-12,
    3.792e-12, 3.407e-12, 2.953e-12, 2.429e-12, 1.931e-12, 1.46e-12,
    1.099e-12, 8.199e-13, 6.077e-13, 4.449e-13, 3.359e-13, 2.524e-13,
    1.881e-13, 1.391e-13, 1.02e-13, 7.544e-14, 5.555e-14, 4.22e-14,
    3.321e-14, 2.686e-14, 2.212e-14, 1.78e-14, 1.369e-14, 1.094e-14,
    9.13e-15, 8.101e-15, 7.828e-15, 8.393e-15, 1.012e-14, 1.259e-14,
    1.538e-14, 1.961e-14, 2.619e-14, 3.679e-14, 5.049e-14, 6.917e-14,
    8.88e-14, 1.115e-13, 1.373e-13, 1.619e-13, 1.878e-13, 2.111e-13,
    2.33e-13, 2.503e-13, 2.613e-13, 2.743e-13, 2.826e-13, 2.976e-13,
    3.162e-13, 3.36e-13, 3.491e-13, 3.541e-13, 3.595e-13, 3.608e-13,
    3.709e-13, 3.869e-13, 4.12e-13, 4.366e-13, 4.504e-13, 4.379e-13,
    3.955e-13, 3.385e-13, 2.741e-13, 2.089e-13, 1.427e-13, 9.294e-14,
    5.775e-14, 3.565e-14, 2.21e-14, 1.398e-14, 9.194e-15, 6.363e-15,
    4.644e-15, 3.55e-15, 2.808e-15, 2.274e-15, 1.871e-15, 1.557e-15,
    1.308e-15, 1.108e-15, 9.488e-16, 8.222e-16, 7.238e-16, 6.506e-16,
    6.008e-16, 5.742e-16, 5.724e-16, 5.991e-16, 6.625e-16, 7.775e-16,
    9.734e-16, 1.306e-15, 1.88e-15, 2.879e-15, 4.616e-15, 7.579e-15,
    1.248e-14, 2.03e-14, 3.244e-14, 5.171e-14, 7.394e-14, 9.676e-14,
    1.199e-13, 1.467e-13, 1.737e-13, 2.02e-13, 2.425e-13, 3.016e-13,
    3.7e-13, 4.617e-13, 5.949e-13, 7.473e-13, 9.378e-13, 1.191e-12,
    1.481e-12, 1.813e-12, 2.232e-12, 2.722e-12, 3.254e-12, 3.845e-12,
    4.458e-12, 5.048e-12, 5.511e-12, 5.898e-12, 6.204e-12, 6.293e-12,
    6.386e-12, 6.467e-12, 6.507e-12, 6.466e-12, 6.443e-12, 6.598e-12,
    6.873e-12, 7.3e-12, 7.816e-12, 8.368e-12, 8.643e-12, 8.466e-12,
    7.871e-12, 6.853e-12, 5.714e-12, 4.482e-12, 3.392e-12, 2.613e-12,
    2.008e-12, 1.562e-12, 1.228e-12, 9.888e-13, 7.646e-13, 5.769e-13,
    4.368e-13, 3.324e-13, 2.508e-13, 1.916e-13
  };

  static double xfcrev[15] =
    { 1.003, 1.009, 1.015, 1.023, 1.029, 1.033, 1.037,
    1.039, 1.04, 1.046, 1.036, 1.027, 1.01, 1.002, 1.
  };

  double a1, a2, a3, dw, ew, dx, xw, xx, vf2, vf6, cw260, cw296,
    sfac, fscal, cwfrn, ctmpth, ctwfrn, ctwslf;

  int iw, jw, ix;

  /* Get H2O continuum absorption... */
  xw = nu / 10 + 1;
  if (xw >= 1 && xw < 2001) {
    iw = (int) xw;
    jw = iw + 1;
    dw = xw - iw;
    ew = 1 - dw;
    cw296 = ew * h2o296[iw - 1] + dw * h2o296[jw - 1];
    cw260 = ew * h2o260[iw - 1] + dw * h2o260[jw - 1];
    cwfrn = ew * h2ofrn[iw - 1] + dw * h2ofrn[jw - 1];
    if (nu <= 820 || nu >= 960) {
      sfac = 1;
    } else {
      xx = (nu - 820) / 10;
      ix = (int) xx;
      dx = xx - ix;
      sfac = (1 - dx) * xfcrev[ix] + dx * xfcrev[ix + 1];
    }
    ctwslf = sfac * cw296 * pow(cw260 / cw296, (296 - t) / (296 - 260));
    vf2 = gsl_pow_2(nu - 370);
    vf6 = gsl_pow_3(vf2);
    fscal = 36100 / (vf2 + vf6 * 1e-8 + 36100) * -.25 + 1;
    ctwfrn = cwfrn * fscal;
    a1 = nu * u * tanh(.7193876 / t * nu);
    a2 = 296 / t;
    a3 = p / P0 * (q * ctwslf + (1 - q) * ctwfrn) * 1e-20;
    ctmpth = a1 * a2 * a3;
  } else
    ctmpth = 0;
  return ctmpth;
}

/*****************************************************************************/

double ctmn2(
  double nu,
  double p,
  double t) {

  static double ba[98] = { 0., 4.45e-8, 5.22e-8, 6.46e-8, 7.75e-8, 9.03e-8,
    1.06e-7, 1.21e-7, 1.37e-7, 1.57e-7, 1.75e-7, 2.01e-7, 2.3e-7,
    2.59e-7, 2.95e-7, 3.26e-7, 3.66e-7, 4.05e-7, 4.47e-7, 4.92e-7,
    5.34e-7, 5.84e-7, 6.24e-7, 6.67e-7, 7.14e-7, 7.26e-7, 7.54e-7,
    7.84e-7, 8.09e-7, 8.42e-7, 8.62e-7, 8.87e-7, 9.11e-7, 9.36e-7,
    9.76e-7, 1.03e-6, 1.11e-6, 1.23e-6, 1.39e-6, 1.61e-6, 1.76e-6,
    1.94e-6, 1.97e-6, 1.87e-6, 1.75e-6, 1.56e-6, 1.42e-6, 1.35e-6,
    1.32e-6, 1.29e-6, 1.29e-6, 1.29e-6, 1.3e-6, 1.32e-6, 1.33e-6,
    1.34e-6, 1.35e-6, 1.33e-6, 1.31e-6, 1.29e-6, 1.24e-6, 1.2e-6,
    1.16e-6, 1.1e-6, 1.04e-6, 9.96e-7, 9.38e-7, 8.63e-7, 7.98e-7,
    7.26e-7, 6.55e-7, 5.94e-7, 5.35e-7, 4.74e-7, 4.24e-7, 3.77e-7,
    3.33e-7, 2.96e-7, 2.63e-7, 2.34e-7, 2.08e-7, 1.85e-7, 1.67e-7,
    1.47e-7, 1.32e-7, 1.2e-7, 1.09e-7, 9.85e-8, 9.08e-8, 8.18e-8,
    7.56e-8, 6.85e-8, 6.14e-8, 5.83e-8, 5.77e-8, 5e-8, 4.32e-8, 0.
  };

  static double betaa[98] = { 802., 802., 761., 722., 679., 646., 609., 562.,
    511., 472., 436., 406., 377., 355., 338., 319., 299., 278., 255.,
    233., 208., 184., 149., 107., 66., 25., -13., -49., -82., -104.,
    -119., -130., -139., -144., -146., -146., -147., -148., -150.,
    -153., -160., -169., -181., -189., -195., -200., -205., -209.,
    -211., -210., -210., -209., -205., -199., -190., -180., -168.,
    -157., -143., -126., -108., -89., -63., -32., 1., 35., 65., 95.,
    121., 141., 152., 161., 164., 164., 161., 155., 148., 143., 137.,
    133., 131., 133., 139., 150., 165., 187., 213., 248., 284., 321.,
    372., 449., 514., 569., 609., 642., 673., 673.
  };

  static double nua[98] = { 2120., 2125., 2130., 2135., 2140., 2145., 2150.,
    2155., 2160., 2165., 2170., 2175., 2180., 2185., 2190., 2195.,
    2200., 2205., 2210., 2215., 2220., 2225., 2230., 2235., 2240.,
    2245., 2250., 2255., 2260., 2265., 2270., 2275., 2280., 2285.,
    2290., 2295., 2300., 2305., 2310., 2315., 2320., 2325., 2330.,
    2335., 2340., 2345., 2350., 2355., 2360., 2365., 2370., 2375.,
    2380., 2385., 2390., 2395., 2400., 2405., 2410., 2415., 2420.,
    2425., 2430., 2435., 2440., 2445., 2450., 2455., 2460., 2465.,
    2470., 2475., 2480., 2485., 2490., 2495., 2500., 2505., 2510.,
    2515., 2520., 2525., 2530., 2535., 2540., 2545., 2550., 2555.,
    2560., 2565., 2570., 2575., 2580., 2585., 2590., 2595., 2600., 2605.
  };

  double b, beta, q_n2 = 0.79, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[97])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 98, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t))
    * q_n2 * b * (q_n2 + (1 - q_n2) * (1.294 - 0.4545 * t / tr));
}

/*****************************************************************************/

double ctmo2(
  double nu,
  double p,
  double t) {

  static double ba[90] = { 0., .061, .074, .084, .096, .12, .162, .208, .246,
    .285, .314, .38, .444, .5, .571, .673, .768, .853, .966, 1.097,
    1.214, 1.333, 1.466, 1.591, 1.693, 1.796, 1.922, 2.037, 2.154,
    2.264, 2.375, 2.508, 2.671, 2.847, 3.066, 3.417, 3.828, 4.204,
    4.453, 4.599, 4.528, 4.284, 3.955, 3.678, 3.477, 3.346, 3.29,
    3.251, 3.231, 3.226, 3.212, 3.192, 3.108, 3.033, 2.911, 2.798,
    2.646, 2.508, 2.322, 2.13, 1.928, 1.757, 1.588, 1.417, 1.253,
    1.109, .99, .888, .791, .678, .587, .524, .464, .403, .357, .32,
    .29, .267, .242, .215, .182, .16, .146, .128, .103, .087, .081,
    .071, .064, 0.
  };

  static double betaa[90] = { 467., 467., 400., 315., 379., 368., 475., 521.,
    531., 512., 442., 444., 430., 381., 335., 324., 296., 248., 215.,
    193., 158., 127., 101., 71., 31., -6., -26., -47., -63., -79.,
    -88., -88., -87., -90., -98., -99., -109., -134., -160., -167.,
    -164., -158., -153., -151., -156., -166., -168., -173., -170.,
    -161., -145., -126., -108., -84., -59., -29., 4., 41., 73., 97.,
    123., 159., 198., 220., 242., 256., 281., 311., 334., 319., 313.,
    321., 323., 310., 315., 320., 335., 361., 378., 373., 338., 319.,
    346., 322., 291., 290., 350., 371., 504., 504.
  };

  static double nua[90] = { 1360., 1365., 1370., 1375., 1380., 1385., 1390.,
    1395., 1400., 1405., 1410., 1415., 1420., 1425., 1430., 1435.,
    1440., 1445., 1450., 1455., 1460., 1465., 1470., 1475., 1480.,
    1485., 1490., 1495., 1500., 1505., 1510., 1515., 1520., 1525.,
    1530., 1535., 1540., 1545., 1550., 1555., 1560., 1565., 1570.,
    1575., 1580., 1585., 1590., 1595., 1600., 1605., 1610., 1615.,
    1620., 1625., 1630., 1635., 1640., 1645., 1650., 1655., 1660.,
    1665., 1670., 1675., 1680., 1685., 1690., 1695., 1700., 1705.,
    1710., 1715., 1720., 1725., 1730., 1735., 1740., 1745., 1750.,
    1755., 1760., 1765., 1770., 1775., 1780., 1785., 1790., 1795.,
    1800., 1805.
  };

  double b, beta, q_o2 = 0.21, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[89])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 90, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t)) * q_o2 * b;
}

/*****************************************************************************/

void copy_atm(
  ctl_t * ctl,
  atm_t * atm_dest,
  atm_t * atm_src,
  int init) {

  int ig, ip, iw;

  size_t s;

  /* Data size... */
  s = (size_t) atm_src->np * sizeof(double);

  /* Copy data... */
  atm_dest->np = atm_src->np;
  memcpy(atm_dest->time, atm_src->time, s);
  memcpy(atm_dest->z, atm_src->z, s);
  memcpy(atm_dest->lon, atm_src->lon, s);
  memcpy(atm_dest->lat, atm_src->lat, s);
  memcpy(atm_dest->p, atm_src->p, s);
  memcpy(atm_dest->t, atm_src->t, s);
  for (ig = 0; ig < ctl->ng; ig++)
    memcpy(atm_dest->q[ig], atm_src->q[ig], s);
  for (iw = 0; iw < ctl->nw; iw++)
    memcpy(atm_dest->k[iw], atm_src->k[iw], s);

  /* Initialize... */
  if (init)
    for (ip = 0; ip < atm_dest->np; ip++) {
      atm_dest->p[ip] = 0;
      atm_dest->t[ip] = 0;
      for (ig = 0; ig < ctl->ng; ig++)
        atm_dest->q[ig][ip] = 0;
      for (iw = 0; iw < ctl->nw; iw++)
        atm_dest->k[iw][ip] = 0;
    }
}

/*****************************************************************************/

void copy_obs(
  ctl_t * ctl,
  obs_t * obs_dest,
  obs_t * obs_src,
  int init) {

  int id, ir;

  size_t s;

  /* Data size... */
  s = (size_t) obs_src->nr * sizeof(double);

  /* Copy data... */
  obs_dest->nr = obs_src->nr;
  memcpy(obs_dest->time, obs_src->time, s);
  memcpy(obs_dest->obsz, obs_src->obsz, s);
  memcpy(obs_dest->obslon, obs_src->obslon, s);
  memcpy(obs_dest->obslat, obs_src->obslat, s);
  memcpy(obs_dest->vpz, obs_src->vpz, s);
  memcpy(obs_dest->vplon, obs_src->vplon, s);
  memcpy(obs_dest->vplat, obs_src->vplat, s);
  memcpy(obs_dest->tpz, obs_src->tpz, s);
  memcpy(obs_dest->tplon, obs_src->tplon, s);
  memcpy(obs_dest->tplat, obs_src->tplat, s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->rad[id], obs_src->rad[id], s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->tau[id], obs_src->tau[id], s);

  /* Initialize... */
  if (init)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs_dest->nr; ir++)
        if (gsl_finite(obs_dest->rad[id][ir])) {
          obs_dest->rad[id][ir] = 0;
          obs_dest->tau[id][ir] = 0;
        }
}

/*****************************************************************************/

int find_emitter(
  ctl_t * ctl,
  const char *emitter) {

  int ig;

  for (ig = 0; ig < ctl->ng; ig++)
    if (strcasecmp(ctl->emitter[ig], emitter) == 0)
      return ig;

  return -1;
}

/*****************************************************************************/

void formod(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs) {

  int id, ir, *mask;

  /* Allocate... */
  ALLOC(mask, int,
        ND * NR);

  /* Save observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      mask[id * NR + ir] = !gsl_finite(obs->rad[id][ir]);

  /* Hydrostatic equilibrium... */
  hydrostatic(ctl, atm);

  /* Claculate pencil beams... */
  for (ir = 0; ir < obs->nr; ir++)
    formod_pencil(ctl, atm, obs, ir);

  /* Apply field-of-view convolution... */
  formod_fov(ctl, obs);

  /* Convert radiance to brightness temperature... */
  if (ctl->write_bbt)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs->nr; ir++)
        obs->rad[id][ir] = brightness(obs->rad[id][ir], ctl->nu[id]);

  /* Apply observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      if (mask[id * NR + ir])
        obs->rad[id][ir] = GSL_NAN;

  /* Free... */
  free(mask);
}

/*****************************************************************************/

void formod_continua(
  ctl_t * ctl,
  los_t * los,
  int ip,
  double *beta) {

  static int ig_co2 = -999, ig_h2o = -999;

  int id;

  /* Extinction... */
  for (id = 0; id < ctl->nd; id++)
    beta[id] = los->k[ctl->window[id]][ip];

  /* CO2 continuum... */
  if (ctl->ctm_co2) {
    if (ig_co2 == -999)
      ig_co2 = find_emitter(ctl, "CO2");
    if (ig_co2 >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmco2(ctl->nu[id], los->p[ip], los->t[ip],
                           los->u[ig_co2][ip]) / los->ds[ip];
  }

  /* H2O continuum... */
  if (ctl->ctm_h2o) {
    if (ig_h2o == -999)
      ig_h2o = find_emitter(ctl, "H2O");
    if (ig_h2o >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmh2o(ctl->nu[id], los->p[ip], los->t[ip],
                           los->q[ig_h2o][ip],
                           los->u[ig_h2o][ip]) / los->ds[ip];
  }

  /* N2 continuum... */
  if (ctl->ctm_n2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmn2(ctl->nu[id], los->p[ip], los->t[ip]);

  /* O2 continuum... */
  if (ctl->ctm_o2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmo2(ctl->nu[id], los->p[ip], los->t[ip]);
}

```

```
/*****************************************************************************/

void formod_fov(
  ctl_t * ctl,
  obs_t * obs) {

  static double dz[NSHAPE], w[NSHAPE];

  static int init = 0, n;

  obs_t *obs2;

  double rad[ND][NR], tau[ND][NR], wsum, z[NR], zfov;

  int i, id, idx, ir, ir2, nz;

  /* Do not take into account FOV... */
  if (ctl->fov[0] == '-')
    return;

  /* Initialize FOV data... */
  if (!init) {
    init = 1;
    read_shape(ctl->fov, dz, w, &n);
  }

  /* Allocate... */
  ALLOC(obs2, obs_t, 1);

  /* Copy observation data... */
  copy_obs(ctl, obs2, obs, 0);

  /* Loop over ray paths... */
  for (ir = 0; ir < obs->nr; ir++) {

    /* Get radiance and transmittance profiles... */
    nz = 0;
    for (ir2 = GSL_MAX(ir - NFOV, 0); ir2 < GSL_MIN(ir + 1 + NFOV, obs->nr);
         ir2++)
      if (obs->time[ir2] == obs->time[ir]) {
        z[nz] = obs2->vpz[ir2];
        for (id = 0; id < ctl->nd; id++) {
          rad[id][nz] = obs2->rad[id][ir2];
          tau[id][nz] = obs2->tau[id][ir2];
        }
        nz++;
      }
    if (nz < 2)
      ERRMSG("Cannot apply FOV convolution!");

    /* Convolute profiles with FOV... */
    wsum = 0;
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] = 0;
      obs->tau[id][ir] = 0;
    }
    for (i = 0; i < n; i++) {
      zfov = obs->vpz[ir] + dz[i];
      idx = locate(z, nz, zfov);
      for (id = 0; id < ctl->nd; id++) {
        obs->rad[id][ir] += w[i]
          * LIN(z[idx], rad[id][idx], z[idx + 1], rad[id][idx + 1], zfov);
        obs->tau[id][ir] += w[i]
          * LIN(z[idx], tau[id][idx], z[idx + 1], tau[id][idx + 1], zfov);
      }
      wsum += w[i];
    }
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] /= wsum;
      obs->tau[id][ir] /= wsum;
    }
  }

  /* Free... */
  free(obs2);
}

/*****************************************************************************/

void formod_pencil(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  int ir) {

  static tbl_t *tbl;

  static int init = 0;

  los_t *los;

  double beta_ctm[ND], eps, src_planck[ND], tau_path[NG][ND], tau_gas[ND];

  int id, ip;

  /* Initialize look-up tables... */
  if (!init) {
    init = 1;
    ALLOC(tbl, tbl_t, 1);
    init_tbl(ctl, tbl);
  }

  /* Allocate... */
  ALLOC(los, los_t, 1);

  /* Initialize... */
  for (id = 0; id < ctl->nd; id++) {
    obs->rad[id][ir] = 0;
    obs->tau[id][ir] = 1;
  }

  /* Raytracing... */
  raytrace(ctl, atm, obs, los, ir);

  /* Loop over LOS points... */
  for (ip = 0; ip < los->np; ip++) {

    /* Get trace gas transmittance... */
    intpol_tbl(ctl, tbl, los, ip, tau_path, tau_gas);

    /* Get continuum absorption... */
    formod_continua(ctl, los, ip, beta_ctm);

    /* Compute Planck function... */
    formod_srcfunc(ctl, tbl, los->t[ip], src_planck);

    /* Loop over channels... */
    for (id = 0; id < ctl->nd; id++)
      if (tau_gas[id] > 0) {

        /* Get segment emissivity... */
        eps = 1 - tau_gas[id] * exp(-beta_ctm[id] * los->ds[ip]);

        /* Compute radiance... */
        obs->rad[id][ir] += src_planck[id] * eps * obs->tau[id][ir];

        /* Compute path transmittance... */
        obs->tau[id][ir] *= (1 - eps);
      }
  }

  /* Add surface... */
  if (los->tsurf > 0) {
    formod_srcfunc(ctl, tbl, los->tsurf, src_planck);
    for (id = 0; id < ctl->nd; id++)
      obs->rad[id][ir] += src_planck[id] * obs->tau[id][ir];
  }

  /* Free... */
  free(los);
}

/*****************************************************************************/

void formod_srcfunc(
  ctl_t * ctl,
  tbl_t * tbl,
  double t,
  double *src) {

  int id, it;

  /* Determine index in temperature array... */
  it = locate(tbl->st, TBLNS, t);

  /* Interpolate Planck function value... */
  for (id = 0; id < ctl->nd; id++)
    src[id] = LIN(tbl->st[it], tbl->sr[id][it],
                  tbl->st[it + 1], tbl->sr[id][it + 1], t);
}

/*****************************************************************************/

void geo2cart(
  double z,
  double lon,
  double lat,
  double *x) {

  double radius;

  radius = z + RE;
  x[0] = radius * cos(lat / 180 * M_PI) * cos(lon / 180 * M_PI);
  x[1] = radius * cos(lat / 180 * M_PI) * sin(lon / 180 * M_PI);
  x[2] = radius * sin(lat / 180 * M_PI);
}

/*****************************************************************************/

double gravity(
  double z,
  double lat) {

  /* Compute gravity according to 1967 Geodetic Reference System... */
  return 9.780318 * (1 + 0.0053024 * gsl_pow_2(sin(lat / 180 * M_PI))
                     - 0.0000058 * gsl_pow_2(sin(2 * lat / 180 * M_PI))) -
    3.086e-3 * z;
}

/*****************************************************************************/

void hydrostatic(
  ctl_t * ctl,
  atm_t * atm) {

  static int ig_h2o = -999;

  double dzmin = 1e99, e = 0, mean, mmair = 28.96456e-3, mmh2o =
    18.0153e-3, z;

  int i, ip, ipref = 0, ipts = 20;

  /* Check reference height... */
  if (ctl->hydz < 0)
    return;

  /* Determine emitter index of H2O... */
  if (ig_h2o == -999)
    ig_h2o = find_emitter(ctl, "H2O");

  /* Find air parcel next to reference height... */
  for (ip = 0; ip < atm->np; ip++)
    if (fabs(atm->z[ip] - ctl->hydz) < dzmin) {
      dzmin = fabs(atm->z[ip] - ctl->hydz);
      ipref = ip;
    }

  /* Upper part of profile... */
  for (ip = ipref + 1; ip < atm->np; ip++) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip - 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip - 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip - 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip - 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip - 1]));
  }

  /* Lower part of profile... */
  for (ip = ipref - 1; ip >= 0; ip--) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip + 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip + 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip + 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip + 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip + 1]));
  }
}

/*****************************************************************************/

void idx2name(
  ctl_t * ctl,
  int idx,
  char *quantity) {

  int ig, iw;

  if (idx == IDXP)
    sprintf(quantity, "PRESSURE");

  if (idx == IDXT)
    sprintf(quantity, "TEMPERATURE");

  for (ig = 0; ig < ctl->ng; ig++)
    if (idx == IDXQ(ig))
      sprintf(quantity, "%s", ctl->emitter[ig]);

  for (iw = 0; iw < ctl->nw; iw++)
    if (idx == IDXK(iw))
      sprintf(quantity, "EXTINCT_WINDOW%d", iw);
}

/*****************************************************************************/

void init_tbl(
  ctl_t * ctl,
  tbl_t * tbl) {

  FILE *in;

  char filename[LEN], line[LEN];

  double eps, eps_old, press, press_old, temp, temp_old, u, u_old,
    f[NSHAPE], fsum, nu[NSHAPE];

  int i, id, ig, ip, it, n;

  /* Loop over trace gases and channels... */
  for (ig = 0; ig < ctl->ng; ig++)
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(in,filename,line,eps,eps_old,press,
press_old,temp,temp_old,u,u_old,id,ip,it)
    for (id = 0; id < ctl->nd; id++) {

      /* Initialize... */
      tbl->np[ig][id] = -1;
      eps_old = -999;
      press_old = -999;
      temp_old = -999;
      u_old = -999;

      /* Try to open file... */
      sprintf(filename, "%s_%.4f_%s.tab",
              ctl->tblbase, ctl->nu[id], ctl->emitter[ig]);
      if (!(in = fopen(filename, "r"))) {
        printf("Missing emissivity table: %s\n", filename);
        continue;
      }
      printf("Read emissivity table: %s\n", filename);

      /* Read data... */
      while (fgets(line, LEN, in)) {

        /* Parse line... */
        if (sscanf(line, "%lg %lg %lg %lg", &press, &temp, &u, &eps) != 4)
          continue;

        /* Determine pressure index... */
        if (press != press_old) {
          press_old = press;
          if ((++tbl->np[ig][id]) >= TBLNP)
            ERRMSG("Too many pressure levels!");
          tbl->nt[ig][id][tbl->np[ig][id]] = -1;
        }

        /* Determine temperature index... */
        if (temp != temp_old) {
          temp_old = temp;
          if ((++tbl->nt[ig][id][tbl->np[ig][id]]) >= TBLNT)
            ERRMSG("Too many temperatures!");
          tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] = -1;
        }

        /* Determine column density index... */
        if ((eps > eps_old && u > u_old) || tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] < 0) {
          eps_old = eps;
          u_old = u;
          if ((++tbl->nu[ig][id][tbl->np[ig][id]]
               [tbl->nt[ig][id][tbl->np[ig][id]]]) >= TBLNU) {
            tbl->nu[ig][id][tbl->np[ig][id]]
              [tbl->nt[ig][id][tbl->np[ig][id]]]--;
            continue;
          }
        }

        /* Store data... */
        tbl->p[ig][id][tbl->np[ig][id]] = press;
        tbl->t[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          = temp;
        tbl->u[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) u;
        tbl->eps[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) eps;
      }

      /* Increment counters... */
      tbl->np[ig][id]++;
      for (ip = 0; ip < tbl->np[ig][id]; ip++) {
        tbl->nt[ig][id][ip]++;
        for (it = 0; it < tbl->nt[ig][id][ip]; it++)
          tbl->nu[ig][id][ip][it]++;
      }

      /* Close file... */
      fclose(in);
    }

  /* Write info... */
  printf("Initialize source function table...\n");

  /* Loop over channels... */
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(filename,it,i,n,f,fsum,nu)
  for (id = 0; id < ctl->nd; id++) {

    /* Read filter function... */
    sprintf(filename, "%s_%.4f.filt", ctl->tblbase, ctl->nu[id]);
    read_shape(filename, nu, f, &n);

    /* Compute source function table... */
    for (it = 0; it < TBLNS; it++) {

      /* Set temperature... */
      tbl->st[it] = LIN(0.0, TMIN, TBLNS - 1.0, TMAX, (double) it);

      /* Integrate Planck function... */
      fsum = 0;
      tbl->sr[id][it] = 0;
      for (i = 0; i < n; i++) {
        fsum += f[i];
        tbl->sr[id][it] += f[i] * planck(tbl->st[it], nu[i]);
      }
      tbl->sr[id][it] /= fsum;
    }
  }
}

/*****************************************************************************/

void intpol_atm(
  ctl_t * ctl,
  atm_t * atm,
  double z,
  double *p,
  double *t,
  double *q,
  double *k) {

  int ig, ip, iw;

  /* Get array index... */
  ip = locate(atm->z, atm->np, z);

  /* Interpolate... */
  *p = EXP(atm->z[ip], atm->p[ip], atm->z[ip + 1], atm->p[ip + 1], z);
  *t = LIN(atm->z[ip], atm->t[ip], atm->z[ip + 1], atm->t[ip + 1], z);
  for (ig = 0; ig < ctl->ng; ig++)
```

```
    q[ig] =
      LIN(atm->z[ip], atm->q[ig][ip], atm->z[ip + 1], atm->q[ig][ip + 1], z);
  for (iw = 0; iw < ctl->nw; iw++)
    k[iw] =
      LIN(atm->z[ip], atm->k[iw][ip], atm->z[ip + 1], atm->k[iw][ip + 1], z);
}

/*****************************************************************************/

void intpol_tbl(
  ctl_t * ctl,
  tbl_t * tbl,
  los_t * los,
  int ip,
  double tau_path[NG][ND],
  double tau_seg[ND]) {

  double eps, eps00, eps01, eps10, eps11, u;

  int id, ig, ipr, it0, it1;

  /* Initialize... */
  if (ip <= 0)
    for (ig = 0; ig < ctl->ng; ig++)
      for (id = 0; id < ctl->nd; id++)
        tau_path[ig][id] = 1;

  /* Loop over channels... */
  for (id = 0; id < ctl->nd; id++) {

    /* Initialize... */
    tau_seg[id] = 1;

    /* Loop over emitters.... */
    for (ig = 0; ig < ctl->ng; ig++) {

      /* Check size of table (pressure)... */
      if (tbl->np[ig][id] < 2)
        eps = 0;

      /* Check transmittance... */
      else if (tau_path[ig][id] < 1e-9)
        eps = 1;

      /* Interpolate... */
      else {

        /* Determine pressure and temperature indices... */
        ipr = locate(tbl->p[ig][id], tbl->np[ig][id], los->p[ip]);
        it0 = locate(tbl->t[ig][id][ipr], tbl->nt[ig][id][ipr], los->t[ip]);
        it1 =
          locate(tbl->t[ig][id][ipr + 1], tbl->nt[ig][id][ipr + 1],
                 los->t[ip]);

        /* Check size of table (temperature and column density)... */
        if (tbl->nt[ig][id][ipr] < 2 || tbl->nt[ig][id][ipr + 1] < 2
            || tbl->nu[ig][id][ipr][it0] < 2
            || tbl->nu[ig][id][ipr][it0 + 1] < 2
            || tbl->nu[ig][id][ipr + 1][it1] < 2
            || tbl->nu[ig][id][ipr + 1][it1 + 1] < 2)
          eps = 0;

        else {

          /* Get emissivities of extended path... */
          u = intpol_tbl_u(tbl, ig, id, ipr, it0, 1 - tau_path[ig][id]);
          eps00 = intpol_tbl_eps(tbl, ig, id, ipr, it0, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr, it0 + 1, 1 - tau_path[ig][id]);
          eps01 =
            intpol_tbl_eps(tbl, ig, id, ipr, it0 + 1, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr + 1, it1, 1 - tau_path[ig][id]);
          eps10 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1, u + los->u[ig][ip]);

          u =
            intpol_tbl_u(tbl, ig, id, ipr + 1, it1 + 1, 1 - tau_path[ig][id]);
          eps11 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1 + 1, u + los->
u[ig][ip]);

          /* Interpolate with respect to temperature... */
          eps00 = LIN(tbl->t[ig][id][ipr][it0], eps00,
                      tbl->t[ig][id][ipr][it0 + 1], eps01, los->t[ip]);
          eps11 = LIN(tbl->t[ig][id][ipr + 1][it1], eps10,
                      tbl->t[ig][id][ipr + 1][it1 + 1], eps11, los->t[ip]);

          /* Interpolate with respect to pressure... */
          eps00 = LIN(tbl->p[ig][id][ipr], eps00,
                      tbl->p[ig][id][ipr + 1], eps11, los->p[ip]);

          /* Check emssivity range... */
          eps00 = GSL_MAX(GSL_MIN(eps00, 1), 0);

          /* Determine segment emissivity... */
          eps = 1 - (1 - eps00) / tau_path[ig][id];
        }
      }

      /* Get transmittance of extended path... */
      tau_path[ig][id] *= (1 - eps);

      /* Get segment transmittance... */
      tau_seg[id] *= (1 - eps);
    }
  }
}

/*****************************************************************************/

double intpol_tbl_eps(
  tbl_t * tbl,
  int ig,
  int id,
  int ip,
  int it,
  double u) {

  int idx;

  /* Lower boundary... */
  if (u < tbl->u[ig][id][ip][it][0])
    return LIN(0, 0, tbl->u[ig][id][ip][it][0], tbl->eps[ig][id][ip][it][0],
               u);

  /* Upper boundary... */
  else if (u > tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1e30, 1, u);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->u[ig][id][ip][it], tbl->nu[ig][id][ip][it], u);

    /* Interpolate... */
    return
      LIN(tbl->u[ig][id][ip][it][idx], tbl->eps[ig][id][ip][it][idx],
          tbl->u[ig][id][ip][it][idx + 1], tbl->eps[ig][id][ip][it][idx + 1],
          u);
  }
}

/*****************************************************************************/

double intpol_tbl_u(
  tbl_t * tbl,
  int ig,
  int id,
  int ip,
  int it,
  double eps) {

  int idx;

  /* Lower boundary... */
  if (eps < tbl->eps[ig][id][ip][it][0])
    return LIN(0, 0, tbl->eps[ig][id][ip][it][0], tbl->u[ig][id][ip][it][0],
               eps);

  /* Upper boundary... */
  else if (eps > tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1, 1e30, eps);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->eps[ig][id][ip][it], tbl->nu[ig][id][ip][it], eps);

    /* Interpolate... */
    return
      LIN(tbl->eps[ig][id][ip][it][idx], tbl->u[ig][id][ip][it][idx],
          tbl->eps[ig][id][ip][it][idx + 1], tbl->u[ig][id][ip][it][idx + 1],
          eps);
  }
}

/*****************************************************************************/

void jsec2time(
  double jsec,
  int *year,
  int *mon,
  int *day,
  int *hour,
  int *min,
  int *sec,
  double *remain) {

  struct tm t0, *t1;

  time_t jsec0;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}

/*****************************************************************************/

void kernel(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  gsl_matrix * k) {

  atm_t *atm1;
  obs_t *obs1;

  gsl_vector *x0, *x1, *yy0, *yy1;

  int *iqa, j;

  double h;

  size_t i, n, m;

  /* Get sizes... */
  m = k->size1;
  n = k->size2;

  /* Allocate... */
  x0 = gsl_vector_alloc(n);
  yy0 = gsl_vector_alloc(m);
  ALLOC(iqa, int,
        N);

  /* Compute radiance for undisturbed atmospheric data... */
  formod(ctl, atm, obs);

  /* Compose vectors... */
  atm2x(ctl, atm, x0, iqa, NULL);
  obs2y(ctl, obs, yy0, NULL, NULL);

  /* Initialize kernel matrix... */
  gsl_matrix_set_zero(k);

  /* Loop over state vector elements... */
#pragma omp parallel for default(none) shared(ctl,atm,obs,k,x0,yy0,n,m,iqa) private(i, j, h, x1, yy1, atm1,
 obs1)
  for (j = 0; j < (int) n; j++) {

    /* Allocate... */
    x1 = gsl_vector_alloc(n);
    yy1 = gsl_vector_alloc(m);
    ALLOC(atm1, atm_t, 1);
    ALLOC(obs1, obs_t, 1);

    /* Set perturbation size... */
    if (iqa[j] == IDXP)
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-7);
    else if (iqa[j] == IDXT)
      h = 1;
    else if (iqa[j] >= IDXQ(0) && iqa[j] < IDXQ(ctl->ng))
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-15);
    else if (iqa[j] >= IDXK(0) && iqa[j] < IDXK(ctl->nw))
      h = 1e-4;
    else
      ERRMSG("Cannot set perturbation size!");

    /* Disturb state vector element... */
    gsl_vector_memcpy(x1, x0);
    gsl_vector_set(x1, (size_t) j, gsl_vector_get(x1, (size_t) j) + h);
    copy_atm(ctl, atm1, atm, 0);
    copy_obs(ctl, obs1, obs, 0);
    x2atm(ctl, x1, atm1);

    /* Compute radiance for disturbed atmospheric data... */
    formod(ctl, atm1, obs1);

    /* Compose measurement vector for disturbed radiance data... */
    obs2y(ctl, obs1, yy1, NULL, NULL);

    /* Compute derivatives... */
    for (i = 0; i < m; i++)
      gsl_matrix_set(k, i, (size_t) j,
                     (gsl_vector_get(yy1, i) - gsl_vector_get(yy0, i)) / h);

    /* Free... */
    gsl_vector_free(x1);
    gsl_vector_free(yy1);
    free(atm1);
    free(obs1);
  }

  /* Free... */
  gsl_vector_free(x0);
  gsl_vector_free(yy0);
  free(iqa);
}

/*****************************************************************************/

int locate(
  double *xx,
  int n,
  double x) {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}

/*****************************************************************************/

int locate_tbl(
  float *xx,
  int n,
  double x) {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  while (ihi > ilo + 1) {
    i = (ihi + ilo) >> 1;
    if (xx[i] > x)
      ihi = i;
    else
      ilo = i;
  }

  return ilo;
}

/*****************************************************************************/

size_t obs2y(
  ctl_t * ctl,
  obs_t * obs,
  gsl_vector * y,
  int *ida,
  int *ira) {

  int id, ir;

  size_t m = 0;

  /* Determine measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        if (y != NULL)
          gsl_vector_set(y, m, obs->rad[id][ir]);
        if (ida != NULL)
          ida[m] = id;
        if (ira != NULL)
          ira[m] = ir;
        m++;
      }

  return m;
}

/*****************************************************************************/

double planck(
  double t,
  double nu) {

  return C1 * gsl_pow_3(nu) / gsl_expm1(C2 * nu / t);
}

/*****************************************************************************/

void raytrace(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  los_t * los,
  int ir) {

  double cosa, d, dmax, dmin = 0, ds, ex0[3], ex1[3], frac, h = 0.02, k[NW],
    lat, lon, n, naux, ng[3], norm, p, q[NG], t, x[3], xh[3],
    xobs[3], xvp[3], z = 1e99, zmax, zmin, zrefrac = 60;

  int i, ig, ip, iw, stop = 0;

  /* Initialize... */
  los->np = 0;
  los->tsurf = -999;
  obs->tpz[ir] = obs->vpz[ir];
  obs->tplon[ir] = obs->vplon[ir];
  obs->tplat[ir] = obs->vplat[ir];

  /* Get altitude range of atmospheric data... */
  gsl_stats_minmax(&zmin, &zmax, atm->z, 1, (size_t) atm->np);

  /* Check observer altitude... */
  if (obs->obsz[ir] < zmin)
    ERRMSG("Observer below surface!");

  /* Check view point altitude... */
  if (obs->vpz[ir] > zmax)
    return;

  /* Determine Cartesian coordinates for observer and view point... */
  geo2cart(obs->obsz[ir], obs->obslon[ir], obs->obslat[ir], xobs);
  geo2cart(obs->vpz[ir], obs->vplon[ir], obs->vplat[ir], xvp);

  /* Determine initial tangent vector... */
  for (i = 0; i < 3; i++)
    ex0[i] = xvp[i] - xobs[i];
  norm = NORM(ex0);
  for (i = 0; i < 3; i++)
    ex0[i] /= norm;

  /* Observer within atmosphere... */
  for (i = 0; i < 3; i++)
    x[i] = xobs[i];

  /* Observer above atmosphere (search entry point)... */
  if (obs->obsz[ir] > zmax) {
    dmax = norm;
    while (fabs(dmin - dmax) > 0.001) {
      d = (dmax + dmin) / 2;
      for (i = 0; i < 3; i++)
        x[i] = xobs[i] + d * ex0[i];
      cart2geo(x, &z, &lon, &lat);
      if (z <= zmax && z > zmax - 0.001)
        break;
      if (z < zmax - 0.0005)
        dmax = d;
      else
        dmin = d;
    }
  }

  /* Ray-tracing... */
  while (1) {

    /* Set step length... */
    ds = ctl->rayds;
    if (ctl->raydz > 0) {
      norm = NORM(x);
      for (i = 0; i < 3; i++)
        xh[i] = x[i] / norm;
      cosa = fabs(DOTP(ex0, xh));
      if (cosa != 0)
        ds = GSL_MIN(ctl->rayds, ctl->raydz / cosa);
    }

    /* Determine geolocation... */
    cart2geo(x, &z, &lon, &lat);

    /* Check if LOS hits the ground or has left atmosphere... */
    if (z < zmin || z > zmax) {
      stop = (z < zmin ? 2 : 1);
      frac =
        ((z <
          zmin ? zmin : zmax) - los->z[los->np - 1]) / (z - los->z[los->np -
                                                                     1]);
      geo2cart(los->z[los->np - 1], los->lon[los->np - 1],
               los->lat[los->np - 1], xh);
      for (i = 0; i < 3; i++)
        x[i] = xh[i] + frac * (x[i] - xh[i]);
      cart2geo(x, &z, &lon, &lat);
      los->ds[los->np - 1] = ds * frac;
      ds = 0;
    }

    /* Interpolate atmospheric data... */
    intpol_atm(ctl, atm, z, &p, &t, q, k);

    /* Save data... */
    los->lon[los->np] = lon;
    los->lat[los->np] = lat;
    los->z[los->np] = z;
    los->p[los->np] = p;
    los->t[los->np] = t;
    for (ig = 0; ig < ctl->ng; ig++)
      los->q[ig][los->np] = q[ig];
    for (iw = 0; iw < ctl->nw; iw++)
      los->k[iw][los->np] = k[iw];
    los->ds[los->np] = ds;

    /* Increment and check number of LOS points... */
    if ((++los->np) > NLOS)
      ERRMSG("Too many LOS points!");

    /* Check stop flag... */
    if (stop) {
      los->tsurf = (stop == 2 ? t : -999);
      break;
    }

    /* Determine refractivity... */
    if (ctl->refrac && z <= zrefrac)
      n = 1 + refractivity(p, t);
    else
      n = 1;

    /* Construct new tangent vector (first term)... */
    for (i = 0; i < 3; i++)
      ex1[i] = ex0[i] * n;

    /* Compute gradient of refractivity... */
    if (ctl->refrac && z <= zrefrac) {
      for (i = 0; i < 3; i++)
        xh[i] = x[i] + 0.5 * ds * ex0[i];
      cart2geo(xh, &z, &lon, &lat);
      intpol_atm(ctl, atm, z, &p, &t, q, k);
      n = refractivity(p, t);
      for (i = 0; i < 3; i++) {
        xh[i] += h;
        cart2geo(xh, &z, &lon, &lat);
        intpol_atm(ctl, atm, z, &p, &t, q, k);
        naux = refractivity(p, t);
        ng[i] = (naux - n) / h;
        xh[i] -= h;
      }
    } else
      for (i = 0; i < 3; i++)
        ng[i] = 0;

    /* Construct new tangent vector (second term)... */
    for (i = 0; i < 3; i++)
      ex1[i] += ds * ng[i];

    /* Normalize new tangent vector... */
    norm = NORM(ex1);
    for (i = 0; i < 3; i++)
      ex1[i] /= norm;

    /* Determine next point of LOS... */
    for (i = 0; i < 3; i++)
      x[i] += 0.5 * ds * (ex0[i] + ex1[i]);

    /* Copy tangent vector... */
    for (i = 0; i < 3; i++)
      ex0[i] = ex1[i];
  }

  /* Get tangent point (to be done before changing segment lengths!)... */
  tangent_point(los, &obs->tpz[ir], &obs->tplon[ir], &obs->
tplat[ir]);

  /* Change segment lengths according to trapezoid rule... */
  for (ip = los->np - 1; ip >= 1; ip--)
    los->ds[ip] = 0.5 * (los->ds[ip - 1] + los->ds[ip]);
  los->ds[0] *= 0.5;

  /* Compute column density... */
  for (ip = 0; ip < los->np; ip++)
    for (ig = 0; ig < ctl->ng; ig++)
      los->u[ig][ip] = 10 * los->q[ig][ip] * los->p[ip]
        / (GSL_CONST_MKSA_BOLTZMANN * los->t[ip]) * los->ds[ip];
}

/*****************************************************************************/

void read_atm(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  atm_t * atm) {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int ig, iw;

  /* Init... */
  atm->np = 0;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read atmospheric data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", atm->time[atm->np]);
    TOK(NULL, tok, "%lg", atm->z[atm->np]);
    TOK(NULL, tok, "%lg", atm->lon[atm->np]);
    TOK(NULL, tok, "%lg", atm->lat[atm->np]);
    TOK(NULL, tok, "%lg", atm->p[atm->np]);
    TOK(NULL, tok, "%lg", atm->t[atm->np]);
    for (ig = 0; ig < ctl->ng; ig++)
      TOK(NULL, tok, "%lg", atm->q[ig][atm->np]);
    for (iw = 0; iw < ctl->nw; iw++)
      TOK(NULL, tok, "%lg", atm->k[iw][atm->np]);

    /* Increment data point counter... */
    if ((++atm->np) > NP)
      ERRMSG("Too many data points!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Could not read any data!");
}

/*****************************************************************************/

void read_ctl(
  int argc,
  char *argv[],
  ctl_t * ctl) {

  int id, ig, iw;

  /* Write info... */
  printf("\nJuelich Rapid Spectral Simulation Code (JURASSIC)\n"
         "(executable: %s | compiled: %s, %s)\n\n",
         argv[0], __DATE__, __TIME__);

  /* Emitters... */
  ctl->ng = (int) scan_ctl(argc, argv, "NG", -1, "0", NULL);
  if (ctl->ng < 0 || ctl->ng > NG)
    ERRMSG("Set 0 <= NG <= MAX!");
  for (ig = 0; ig < ctl->ng; ig++)
    scan_ctl(argc, argv, "EMITTER", ig, "", ctl->emitter[ig]);

  /* Radiance channels... */
  ctl->nd = (int) scan_ctl(argc, argv, "ND", -1, "0", NULL);
  if (ctl->nd < 0 || ctl->nd > ND)
    ERRMSG("Set 0 <= ND <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->nu[id] = scan_ctl(argc, argv, "NU", id, "", NULL);

  /* Spectral windows... */
  ctl->nw = (int) scan_ctl(argc, argv, "NW", -1, "1", NULL);
  if (ctl->nw < 0 || ctl->nw > NW)
    ERRMSG("Set 0 <= NW <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->window[id] = (int) scan_ctl(argc, argv, "WINDOW", id, "0", NULL);

  /* Emissivity look-up tables... */
  scan_ctl(argc, argv, "TBLBASE", -1, "-", ctl->tblbase);

  /* Hydrostatic equilibrium... */
  ctl->hydz = scan_ctl(argc, argv, "HYDZ", -1, "-999", NULL);

  /* Continua... */
  ctl->ctm_co2 = (int) scan_ctl(argc, argv, "CTM_CO2", -1, "1", NULL);
  ctl->ctm_h2o = (int) scan_ctl(argc, argv, "CTM_H2O", -1, "1", NULL);
  ctl->ctm_n2 = (int) scan_ctl(argc, argv, "CTM_N2", -1, "1", NULL);
  ctl->ctm_o2 = (int) scan_ctl(argc, argv, "CTM_O2", -1, "1", NULL);

  /* Ray-tracing... */
  ctl->refrac = (int) scan_ctl(argc, argv, "REFRAC", -1, "1", NULL);
  ctl->rayds = scan_ctl(argc, argv, "RAYDS", -1, "10", NULL);
  ctl->raydz = scan_ctl(argc, argv, "RAYDZ", -1, "0.5", NULL);

  /* Field of view... */
  scan_ctl(argc, argv, "FOV", -1, "-", ctl->fov);

  /* Retrieval interface... */
  ctl->retp_zmin = scan_ctl(argc, argv, "RETP_ZMIN", -1, "-999", NULL);
  ctl->retp_zmax = scan_ctl(argc, argv, "RETP_ZMAX", -1, "-999", NULL);
  ctl->rett_zmin = scan_ctl(argc, argv, "RETT_ZMIN", -1, "-999", NULL);
  ctl->rett_zmax = scan_ctl(argc, argv, "RETT_ZMAX", -1, "-999", NULL);
  for (ig = 0; ig < ctl->ng; ig++) {
    ctl->retq_zmin[ig] = scan_ctl(argc, argv, "RETQ_ZMIN", ig, "-999", NULL);
    ctl->retq_zmax[ig] = scan_ctl(argc, argv, "RETQ_ZMAX", ig, "-999", NULL);
  }
  for (iw = 0; iw < ctl->nw; iw++) {
    ctl->retk_zmin[iw] = scan_ctl(argc, argv, "RETK_ZMIN", iw, "-999", NULL);
    ctl->retk_zmax[iw] = scan_ctl(argc, argv, "RETK_ZMAX", iw, "-999", NULL);
  }

  /* Output flags... */
  ctl->write_bbt = (int) scan_ctl(argc, argv, "WRITE_BBT", -1, "0", NULL);
  ctl->write_matrix =
    (int) scan_ctl(argc, argv, "WRITE_MATRIX", -1, "0", NULL);
}

/*****************************************************************************/

void read_matrix(
  const char *dirname,
  const char *filename,
  gsl_matrix * matrix) {

  FILE *in;

  char dum[LEN], file[LEN], line[LEN];

  double value;

  int i, j;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read matrix: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  gsl_matrix_set_zero(matrix);
  while (fgets(line, LEN, in))
    if (sscanf(line, "%d %s %s %s %s %s %d %s %s %s %s %s %lg",
               &i, dum, dum, dum, dum, dum,
               &j, dum, dum, dum, dum, dum, &value) == 13)
      gsl_matrix_set(matrix, (size_t) i, (size_t) j, value);

  /* Close file... */
  fclose(in);
}

/*****************************************************************************/

void read_obs(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  obs_t * obs) {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int id;

  /* Init... */
  obs->nr = 0;

  /* Set filename... */
  if (dirname != NULL)
```

```
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read observation data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", obs->time[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obsz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplat[obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->rad[id][obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->tau[id][obs->nr]);

    /* Increment counter... */
    if ((++obs->nr) > NR)
      ERRMSG("Too many rays!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (obs->nr < 1)
    ERRMSG("Could not read any data!");
}

/*****************************************************************************/

void read_shape(
  const char *filename,
  double *x,
  double *y,
  int *n) {

  FILE *in;

  char line[LEN];

  /* Write info... */
  printf("Read shape function: %s\n", filename);

  /* Open file... */
  if (!(in = fopen(filename, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  *n = 0;
  while (fgets(line, LEN, in))
    if (sscanf(line, "%lg %lg", &x[*n], &y[*n]) == 2)
      if ((++(*n)) > NSHAPE)
        ERRMSG("Too many data points!");

  /* Check number of points... */
  if (*n < 1)
    ERRMSG("Could not read any data!");

  /* Close file... */
  fclose(in);
}

/*****************************************************************************/

double refractivity(
  double p,
  double t) {

  /* Refractivity of air at 4 to 15 micron... */
  return 7.753e-05 * p / t;
}

```

```
/*****************************************************************************/

double scan_ctl(
  int argc,
  char *argv[],
  const char *varname,
  int arridx,
  const char *defvalue,
  char *value) {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (argv[1][0] != '-')
    if (!(in = fopen(argv[1], "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
    sprintf(value, "%s", rval);
  return atof(rval);
}

/*****************************************************************************/

void tangent_point(
  los_t * los,
  double *tpz,
  double *tplon,
  double *tplat) {

  double a, b, c, dummy, v[3], v0[3], v2[3], x, x1, x2, yy0, yy1, yy2;

  size_t i, ip;

  /* Find minimum altitude... */
  ip = gsl_stats_min_index(los->z, 1, (size_t) los->np);

  /* Nadir or zenith... */
  if (ip <= 0 || ip >= (size_t) los->np - 1) {
    *tpz = los->z[los->np - 1];
    *tplon = los->lon[los->np - 1];
    *tplat = los->lat[los->np - 1];
  }

  /* Limb... */
  else {

    /* Determine interpolating polynomial y=a*x^2+b*x+c... */
    yy0 = los->z[ip - 1];
    yy1 = los->z[ip];
    yy2 = los->z[ip + 1];
    x1 = sqrt(gsl_pow_2(los->ds[ip]) - gsl_pow_2(yy1 - yy0));
    x2 = x1 + sqrt(gsl_pow_2(los->ds[ip + 1]) - gsl_pow_2(yy2 - yy1));
    a = 1 / (x1 - x2) * (-(yy0 - yy1) / x1 + (yy0 - yy2) / x2);
    b = -(yy0 - yy1) / x1 - a * x1;
    c = yy0;

    /* Get tangent point location... */
    x = -b / (2 * a);
    *tpz = a * x * x + b * x + c;
    geo2cart(los->z[ip - 1], los->lon[ip - 1], los->lat[ip - 1], v0);
    geo2cart(los->z[ip + 1], los->lon[ip + 1], los->lat[ip + 1], v2);
    for (i = 0; i < 3; i++)
      v[i] = LIN(0.0, v0[i], x2, v2[i], x);
    cart2geo(v, &dummy, tplon, tplat);
  }
}

/*****************************************************************************/

void time2jsec(
  int year,
  int mon,
  int day,
  int hour,
  int min,
  int sec,
  double remain,
  double *jsec) {

  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}

/*****************************************************************************/

void timer(
  const char *name,
  const char *file,
  const char *func,
  int line,
  int mode) {

  static double dt_w, w0[10];

  static int l0[10], nt;

  struct timeval tim;

  /* Start new timer... */
  if (mode == 1) {
    gettimeofday(&tim, NULL);
    w0[nt] = (double) tim.tv_sec + (double) tim.tv_usec / 1e6;
    l0[nt] = line;
    if ((++nt) >= 10)
      ERRMSG("Too many timers!");
  }

  /* Write elapsed time... */
  else {

    /* Check timer index... */
    if (nt - 1 < 0)
      ERRMSG("Coding error!");

    /* Get time differences... */
    gettimeofday(&tim, NULL);
    dt_w = (double) tim.tv_sec + (double) tim.tv_usec / 1e6 - w0[nt - 1];

    /* Write elapsed time... */
    printf("Timer '%s' (%s, %s, l%d-%d): %.3f sec\n",
           name, file, func, l0[nt - 1], line, dt_w);
  }

  /* Stop timer... */
  if (mode == 3)
    nt--;
}

/*****************************************************************************/

void write_atm(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  atm_t * atm) {

  FILE *out;

  char file[LEN];

  int ig, ip, iw, n = 6;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write atmospheric data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n" "# $6 = temperature [K]\n");
  for (ig = 0; ig < ctl->ng; ig++)
    fprintf(out, "# $%d = %s volume mixing ratio\n", ++n, ctl->emitter[ig]);
  for (iw = 0; iw < ctl->nw; iw++)
    fprintf(out, "# $%d = window %d: extinction [1/km]\n", ++n, iw);

  /* Write data... */
  for (ip = 0; ip < atm->np; ip++) {
    if (ip == 0 || atm->lat[ip] != atm->lat[ip - 1]
        || atm->lon[ip] != atm->lon[ip - 1])
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g", atm->time[ip], atm->z[ip],
            atm->lon[ip], atm->lat[ip], atm->p[ip], atm->t[ip]);
    for (ig = 0; ig < ctl->ng; ig++)
      fprintf(out, " %g", atm->q[ig][ip]);
    for (iw = 0; iw < ctl->nw; iw++)
      fprintf(out, " %g", atm->k[iw][ip]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}

/*****************************************************************************/

void write_matrix(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  gsl_matrix * matrix,
  atm_t * atm,
  obs_t * obs,
  const char *rowspace,
  const char *colspace,
  const char *sort) {

  FILE *out;

  char file[LEN], quantity[LEN];

  int *cida, *ciqa, *cipa, *cira, *rida, *riqa, *ripa, *rira;

  size_t i, j, nc, nr;

  /* Check output flag... */
  if (!ctl->write_matrix)
    return;

  /* Allocate... */
  ALLOC(cida, int, M);
  ALLOC(ciqa, int,
        N);
  ALLOC(cipa, int,
        N);
  ALLOC(cira, int,
        M);
  ALLOC(rida, int,
        M);
  ALLOC(riqa, int,
        N);
  ALLOC(ripa, int,
        N);
  ALLOC(rira, int,
        M);

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write matrix: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header (row space)... */
  if (rowspace[0] == 'y') {

    fprintf(out,
            "# $1 = Row: index (measurement space)\n"
            "# $2 = Row: channel wavenumber [cm^-1]\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: view point altitude [km]\n"
            "# $5 = Row: view point longitude [deg]\n"
            "# $6 = Row: view point latitude [deg]\n");

    /* Get number of rows... */
    nr = obs2y(ctl, obs, NULL, rida, rira);

  } else {

    fprintf(out,
            "# $1 = Row: index (state space)\n"
            "# $2 = Row: name of quantity\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: altitude [km]\n"
            "# $5 = Row: longitude [deg]\n" "# $6 = Row: latitude [deg]\n");

    /* Get number of rows... */
    nr = atm2x(ctl, atm, NULL, riqa, ripa);
  }

  /* Write header (column space)... */
  if (colspace[0] == 'y') {

    fprintf(out,
            "# $7 = Col: index (measurement space)\n"
            "# $8 = Col: channel wavenumber [cm^-1]\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: view point altitude [km]\n"
            "# $11 = Col: view point longitude [deg]\n"
            "# $12 = Col: view point latitude [deg]\n");

    /* Get number of columns... */
    nc = obs2y(ctl, obs, NULL, cida, cira);

  } else {

    fprintf(out,
            "# $7 = Col: index (state space)\n"
            "# $8 = Col: name of quantity\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: altitude [km]\n"
            "# $11 = Col: longitude [deg]\n" "# $12 = Col: latitude [deg]\n");

    /* Get number of columns... */
    nc = atm2x(ctl, atm, NULL, ciqa, cipa);
  }

  /* Write header entry... */
  fprintf(out, "# $13 = Matrix element\n\n");

  /* Write matrix data... */
  i = j = 0;
  while (i < nr && j < nc) {

    /* Write info about the row... */
    if (rowspace[0] == 'y')
      fprintf(out, "%d %g %.2f %g %g %g",
              (int) i, ctl->nu[rida[i]],
              obs->time[rira[i]], obs->vpz[rira[i]],
              obs->vplon[rira[i]], obs->vplat[rira[i]]);
    else {
      idx2name(ctl, riqa[i], quantity);
      fprintf(out, "%d %s %.2f %g %g %g", (int) i, quantity,
              atm->time[ripa[i]], atm->z[ripa[i]],
              atm->lon[ripa[i]], atm->lat[ripa[i]]);
    }

    /* Write info about the column... */
    if (colspace[0] == 'y')
      fprintf(out, " %d %g %.2f %g %g %g",
              (int) j, ctl->nu[cida[j]],
              obs->time[cira[j]], obs->vpz[cira[j]],
              obs->vplon[cira[j]], obs->vplat[cira[j]]);
    else {
      idx2name(ctl, ciqa[j], quantity);
      fprintf(out, " %d %s %.2f %g %g %g", (int) j, quantity,
              atm->time[cipa[j]], atm->z[cipa[j]],
              atm->lon[cipa[j]], atm->lat[cipa[j]]);
    }

    /* Write matrix entry... */
    fprintf(out, " %g\n", gsl_matrix_get(matrix, i, j));

    /* Set matrix indices... */
    if (sort[0] == 'r') {
      j++;
      if (j >= nc) {
        j = 0;
        i++;
        fprintf(out, "\n");
      }
    } else {
      i++;
      if (i >= nr) {
        i = 0;
        j++;
        fprintf(out, "\n");
      }
    }
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(cida);
  free(ciqa);
  free(cipa);
  free(cira);
  free(rida);
  free(riqa);
  free(ripa);
  free(rira);
}

/*****************************************************************************/

void write_obs(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  obs_t * obs) {

```

```
  FILE *out;

  char file[LEN];

  int id, ir, n = 10;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write observation data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = observer altitude [km]\n"
          "# $3 = observer longitude [deg]\n"
          "# $4 = observer latitude [deg]\n"
          "# $5 = view point altitude [km]\n"
          "# $6 = view point longitude [deg]\n"
          "# $7 = view point latitude [deg]\n"
          "# $8 = tangent point altitude [km]\n"
          "# $9 = tangent point longitude [deg]\n"
          "# $10 = tangent point latitude [deg]\n");
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: radiance [W/(m^2 sr cm^-1)]\n",
            ++n, ctl->nu[id]);
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: transmittance\n", ++n, ctl->nu[id]);

  /* Write data... */
  for (ir = 0; ir < obs->nr; ir++) {
    if (ir == 0 || obs->time[ir] != obs->time[ir - 1])
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g", obs->time[ir],
            obs->obsz[ir], obs->obslon[ir], obs->obslat[ir],
            obs->vpz[ir], obs->vplon[ir], obs->vplat[ir],
            obs->tpz[ir], obs->tplon[ir], obs->tplat[ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->rad[id][ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->tau[id][ir]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}

/*****************************************************************************/

void x2atm(
  ctl_t * ctl,
  gsl_vector * x,
  atm_t * atm) {

  int ig, iw;

  size_t n = 0;

  /* Set pressure... */
  x2atm_help(atm, ctl->retp_zmin, ctl->retp_zmax, atm->
p, x, &n);

  /* Set temperature... */
  x2atm_help(atm, ctl->rett_zmin, ctl->rett_zmax, atm->
t, x, &n);

  /* Set volume mixing ratio... */
  for (ig = 0; ig < ctl->ng; ig++)
    x2atm_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], x, &n);

  /* Set extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    x2atm_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], x, &n);
}

/*****************************************************************************/
```

```

void x2atm_help(
  atm_t * atm,
  double zmin,
  double zmax,
  double *value,
  gsl_vector * x,
  size_t * n) {

  int ip;

  /* Extract state vector elements... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      value[ip] = gsl_vector_get(x, *n);
      (*n)++;
    }
}

/*****************************************************************************/

void y2obs(
  ctl_t * ctl,
  gsl_vector * y,
  obs_t * obs) {

  int id, ir;

  size_t m = 0;

  /* Decompose measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        obs->rad[id][ir] = gsl_vector_get(y, m);
        m++;
      }
}
```

5.15 jurassic.h File Reference

JURASSIC library declarations.

Data Structures

- struct atm_t

    Atmospheric data.
- struct ctl_t

    Forward model control parameters.
- struct los_t

    Line-of-sight data.
- struct obs_t

    Observation geometry and radiance data.
- struct tbl_t

    Emissivity look-up tables.

Functions

- size_t atm2x (ctl_t ∗ctl, atm_t ∗atm, gsl_vector ∗x, int ∗iqa, int ∗ipa)

    Compose state vector or parameter vector.
- void atm2x_help (atm_t ∗atm, double zmin, double zmax, double ∗value, int val_iqa, gsl_vector ∗x, int ∗iqa, int ∗ipa, size_t ∗n)

    Add elements to state vector.
- double brightness (double rad, double nu)

Compute brightness temperature.
- void cart2geo (double ∗x, double ∗z, double ∗lon, double ∗lat)

  Convert Cartesian coordinates to geolocation.
- void climatology (ctl_t ∗ctl, atm_t ∗atm_mean)

  Interpolate climatological data.
- double ctmco2 (double nu, double p, double t, double u)

  Compute carbon dioxide continuum (optical depth).
- double ctmh2o (double nu, double p, double t, double q, double u)

  Compute water vapor continuum (optical depth).
- double ctmn2 (double nu, double p, double t)

  Compute nitrogen continuum (absorption coefficient).
- double ctmo2 (double nu, double p, double t)

  Compute oxygen continuum (absorption coefficient).
- void copy_atm (ctl_t ∗ctl, atm_t ∗atm_dest, atm_t ∗atm_src, int init)

  Copy and initialize atmospheric data.
- void copy_obs (ctl_t ∗ctl, obs_t ∗obs_dest, obs_t ∗obs_src, int init)

  Copy and initialize observation data.
- int find_emitter (ctl_t ∗ctl, const char ∗emitter)

  Find index of an emitter.
- void formod (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs)

  Determine ray paths and compute radiative transfer.
- void formod_continua (ctl_t ∗ctl, los_t ∗los, int ip, double ∗beta)

  Compute absorption coefficient of continua.
- void formod_fov (ctl_t ∗ctl, obs_t ∗obs)

  Apply field of view convolution.
- void formod_pencil (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, int ir)

  Compute radiative transfer for a pencil beam.
- void formod_srcfunc (ctl_t ∗ctl, tbl_t ∗tbl, double t, double ∗src)

  Compute Planck source function.
- void geo2cart (double z, double lon, double lat, double ∗x)

  Convert geolocation to Cartesian coordinates.
- double gravity (double z, double lat)

  Determine gravity of Earth.
- void hydrostatic (ctl_t ∗ctl, atm_t ∗atm)

  Set hydrostatic equilibrium.
- void idx2name (ctl_t ∗ctl, int idx, char ∗quantity)

  Determine name of state vector quantity for given index.
- void init_tbl (ctl_t ∗ctl, tbl_t ∗tbl)

  Initialize look-up tables.
- void intpol_atm (ctl_t ∗ctl, atm_t ∗atm, double z, double ∗p, double ∗t, double ∗q, double ∗k)

  Interpolate atmospheric data.
- void intpol_tbl (ctl_t ∗ctl, tbl_t ∗tbl, los_t ∗los, int ip, double tau_path[NG][ND], double tau_seg[ND])

  Get transmittance from look-up tables.
- double intpol_tbl_eps (tbl_t ∗tbl, int ig, int id, int ip, int it, double u)

  Interpolate emissivity from look-up tables.
- double intpol_tbl_u (tbl_t ∗tbl, int ig, int id, int ip, int it, double eps)

  Interpolate column density from look-up tables.
- void jsec2time (double jsec, int ∗year, int ∗mon, int ∗day, int ∗hour, int ∗min, int ∗sec, double ∗remain)

  Convert seconds to date.
- void kernel (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, gsl_matrix ∗k)

  Compute Jacobians.

- int locate (double ∗xx, int n, double x)

    Find array index.
- int locate_tbl (float ∗xx, int n, double x)

    Find array index in float array.
- size_t obs2y (ctl_t ∗ctl, obs_t ∗obs, gsl_vector ∗y, int ∗ida, int ∗ira)

    Compose measurement vector.
- double planck (double t, double nu)

    Compute Planck function.
- void raytrace (ctl_t ∗ctl, atm_t ∗atm, obs_t ∗obs, los_t ∗los, int ir)

    Do ray-tracing to determine LOS.
- void read_atm (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

    Read atmospheric data.
- void read_ctl (int argc, char ∗argv[ ], ctl_t ∗ctl)

    Read forward model control parameters.
- void read_matrix (const char ∗dirname, const char ∗filename, gsl_matrix ∗matrix)

    Read matrix.
- void read_obs (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, obs_t ∗obs)

    Read observation data.
- void read_shape (const char ∗filename, double ∗x, double ∗y, int ∗n)

    Read shape function.
- double refractivity (double p, double t)

    Compute refractivity (return value is n - 1).
- double scan_ctl (int argc, char ∗argv[ ], const char ∗varname, int arridx, const char ∗defvalue, char ∗value)

    Search control parameter file for variable entry.
- void tangent_point (los_t ∗los, double ∗tpz, double ∗tplon, double ∗tplat)

    Find tangent point of a given LOS.
- void time2jsec (int year, int mon, int day, int hour, int min, int sec, double remain, double ∗jsec)

    Convert date to seconds.
- void timer (const char ∗name, const char ∗file, const char ∗func, int line, int mode)

    Measure wall-clock time.
- void write_atm (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, atm_t ∗atm)

    Write atmospheric data.
- void write_matrix (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, gsl_matrix ∗matrix, atm_t ∗atm, obs_t ∗obs, const char ∗rowspace, const char ∗colspace, const char ∗sort)

    Write matrix.
- void write_obs (const char ∗dirname, const char ∗filename, ctl_t ∗ctl, obs_t ∗obs)

    Write observation data.
- void x2atm (ctl_t ∗ctl, gsl_vector ∗x, atm_t ∗atm)

    Decompose parameter vector or state vector.
- void x2atm_help (atm_t ∗atm, double zmin, double zmax, double ∗value, gsl_vector ∗x, size_t ∗n)

    Extract elements from state vector.
- void y2obs (ctl_t ∗ctl, gsl_vector ∗y, obs_t ∗obs)

    Decompose measurement vector.

5.15.1 Detailed Description

JURASSIC library declarations.

Definition in file jurassic.h.

5.15.2 Function Documentation

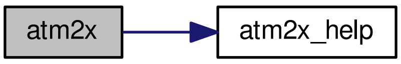
5.15.2.1 size_t atm2x (ctl_t * *ctl*, atm_t * *atm*, gsl_vector * *x*, int * *iqa*, int * *ipa*)

Compose state vector or parameter vector.

Definition at line 29 of file jurassic.c.

```
                {

  int ig, iw;

  size_t n = 0;

  /* Add pressure... */
  atm2x_help(atm, ctl->retp_zmin, ctl->retp_zmax,
             atm->p, IDXP, x, iqa, ipa, &n);

  /* Add temperature... */
  atm2x_help(atm, ctl->rett_zmin, ctl->rett_zmax,
             atm->t, IDXT, x, iqa, ipa, &n);

  /* Add volume mixing ratios... */
  for (ig = 0; ig < ctl->ng; ig++)
    atm2x_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], IDXQ(ig), x, iqa, ipa, &n);

  /* Add extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    atm2x_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], IDXK(iw), x, iqa, ipa, &n);

  return n;
}
```

Here is the call graph for this function:



5.15.2.2 void atm2x_help (atm_t * *atm*, double *zmin*, double *zmax*, double * *value*, int *val_iqa*, gsl_vector * *x*, int * *iqa*, int * *ipa*, size_t * *n*)

Add elements to state vector.

Definition at line 63 of file jurassic.c.

```
                  {

  int ip;

  /* Add elements to state vector... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      if (x != NULL)
        gsl_vector_set(x, *n, value[ip]);
      if (iqa != NULL)
        iqa[*n] = val_iqa;
      if (ipa != NULL)
        ipa[*n] = ip;
      (*n)++;
    }
}
```

5.15.2.3 double brightness (double *rad,* double *nu*)

Compute brightness temperature.

Definition at line 91 of file jurassic.c.

```
               {

  return C2 * nu / gsl_log1p(C1 * gsl_pow_3(nu) / rad);
}
```

5.15.2.4 void cart2geo (double ∗ *x,* double ∗ *z,* double ∗ *lon,* double ∗ *lat*)

Convert Cartesian coordinates to geolocation.

Definition at line 101 of file jurassic.c.

```
                 {

  double radius;

  radius = NORM(x);
  *lat = asin(x[2] / radius) * 180 / M_PI;
  *lon = atan2(x[1], x[0]) * 180 / M_PI;
  *z = radius - RE;
}
```

5.15.2.5 void climatology (ctl_t ∗ *ctl,* atm_t ∗ *atm_mean*)

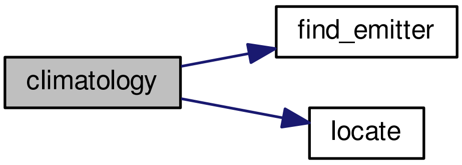
Interpolate climatological data.

Definition at line 117 of file jurassic.c.

```
                 {

  static double z[121] = {
    0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
    20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37,
    38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
    56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73,
    74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91,
    92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107,
    108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120
  };

  static double pre[121] = {
    1017, 901.083, 796.45, 702.227, 617.614, 541.644, 473.437, 412.288,
    357.603, 308.96, 265.994, 228.348, 195.619, 167.351, 143.039, 122.198,
    104.369, 89.141, 76.1528, 65.0804, 55.641, 47.591, 40.7233, 34.8637,
    29.8633, 25.5956, 21.9534, 18.8445, 16.1909, 13.9258, 11.9913,
    10.34, 8.92988, 7.72454, 6.6924, 5.80701, 5.04654, 4.39238, 3.82902,
    3.34337, 2.92413, 2.56128, 2.2464, 1.97258, 1.73384, 1.52519, 1.34242,
    1.18197, 1.04086, 0.916546, 0.806832, 0.709875, 0.624101, 0.548176,
    0.480974, 0.421507, 0.368904, 0.322408, 0.281386, 0.245249, 0.213465,
    0.185549, 0.161072, 0.139644, 0.120913, 0.104568, 0.0903249, 0.0779269,
    0.0671493, 0.0577962, 0.0496902, 0.0426736, 0.0366093, 0.0313743,
    0.0268598, 0.0229699, 0.0196206, 0.0167399, 0.0142646, 0.0121397,
    0.0103181, 0.00875775, 0.00742226, 0.00628076, 0.00530519, 0.00447183,
    0.00376124, 0.00315632, 0.00264248, 0.00220738, 0.00184003, 0.00153095,
    0.00127204, 0.00105608, 0.000876652, 0.00072798, 0.00060492,
    0.000503201, 0.000419226, 0.000349896, 0.000292659, 0.000245421,
    0.000206394, 0.000174125, 0.000147441, 0.000125333, 0.000106985,
    9.173e-05, 7.90172e-05, 6.84172e-05, 5.95574e-05, 5.21183e-05,
    4.58348e-05, 4.05127e-05, 3.59987e-05, 3.21583e-05, 2.88718e-05,
    2.60322e-05, 2.35687e-05, 2.14263e-05, 1.95489e-05
  };

  static double tem[121] = {
    285.14, 279.34, 273.91, 268.3, 263.24, 256.55, 250.2, 242.82, 236.17,
    229.87, 225.04, 221.19, 218.85, 217.19, 216.2, 215.68, 215.42, 215.55,
  215.92, 216.4, 216.93, 217.45, 218, 218.68, 219.39, 220.25, 221.3,
  222.41, 223.88, 225.42, 227.2, 229.52, 231.89, 234.51, 236.85, 239.42,
  241.94, 244.57, 247.36, 250.32, 253.34, 255.82, 258.27, 260.39,
  262.03, 263.45, 264.2, 264.78, 264.67, 264.38, 263.24, 262.03, 260.02,
  258.09, 255.63, 253.28, 250.43, 247.81, 245.26, 242.77, 240.38,
  237.94, 235.79, 233.53, 231.5, 229.53, 227.6, 225.62, 223.77, 222.06,
  220.33, 218.69, 217.18, 215.64, 214.13, 212.52, 210.86, 209.25,
  207.49, 205.81, 204.11, 202.22, 200.32, 198.39, 195.92, 193.46,
  190.94, 188.31, 185.82, 183.57, 181.43, 179.74, 178.64, 178.1, 178.25,
  178.7, 179.41, 180.67, 182.31, 184.18, 186.6, 189.53, 192.66, 196.54,
  201.13, 205.93, 211.73, 217.86, 225, 233.53, 242.57, 252.14, 261.48,
  272.97, 285.26, 299.12, 312.2, 324.17, 338.34, 352.56, 365.28
};

static double c2h2[121] = {
  1.352e-09, 2.83e-10, 1.269e-10, 6.926e-11, 4.346e-11, 2.909e-11,
  2.014e-11, 1.363e-11, 8.71e-12, 5.237e-12, 2.718e-12, 1.375e-12,
  5.786e-13, 2.16e-13, 7.317e-14, 2.551e-14, 1.055e-14, 4.758e-15,
  2.056e-15, 7.703e-16, 2.82e-16, 1.035e-16, 4.382e-17, 1.946e-17,
  9.638e-18, 5.2e-18, 2.811e-18, 1.494e-18, 7.925e-19, 4.213e-19,
  1.998e-19, 8.78e-20, 3.877e-20, 1.728e-20, 7.743e-21, 3.536e-21,
  1.623e-21, 7.508e-22, 3.508e-22, 1.65e-22, 7.837e-23, 3.733e-23,
  1.808e-23, 8.77e-24, 4.285e-24, 2.095e-24, 1.032e-24, 5.082e-25,
  2.506e-25, 1.236e-25, 6.088e-26, 2.996e-26, 1.465e-26, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double c2h6[121] = {
  2.667e-09, 2.02e-09, 1.658e-09, 1.404e-09, 1.234e-09, 1.109e-09,
  1.012e-09, 9.262e-10, 8.472e-10, 7.71e-10, 6.932e-10, 6.216e-10,
  5.503e-10, 4.87e-10, 4.342e-10, 3.861e-10, 3.347e-10, 2.772e-10,
  2.209e-10, 1.672e-10, 1.197e-10, 8.536e-11, 5.783e-11, 3.846e-11,
  2.495e-11, 1.592e-11, 1.017e-11, 6.327e-12, 3.895e-12, 2.403e-12,
  1.416e-12, 8.101e-13, 4.649e-13, 2.686e-13, 1.557e-13, 9.14e-14,
  5.386e-14, 3.19e-14, 1.903e-14, 1.14e-14, 6.875e-15, 4.154e-15,
  2.538e-15, 1.553e-15, 9.548e-16, 5.872e-16, 3.63e-16, 2.244e-16,
  1.388e-16, 8.587e-17, 5.308e-17, 3.279e-17, 2.017e-17, 1.238e-17,
  7.542e-18, 4.585e-18, 2.776e-18, 1.671e-18, 9.985e-19, 5.937e-19,
  3.518e-19, 2.07e-19, 1.215e-19, 7.06e-20, 4.097e-20, 2.37e-20,
  1.363e-20, 7.802e-21, 4.441e-21, 2.523e-21, 1.424e-21, 8.015e-22,
  4.497e-22, 2.505e-22, 1.391e-22, 7.691e-23, 4.238e-23, 2.331e-23,
  1.274e-23, 6.929e-24, 3.752e-24, 2.02e-24, 1.083e-24, 5.774e-25,
  3.041e-25, 1.593e-25, 8.308e-26, 4.299e-26, 2.195e-26, 1.112e-26,
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0, 0
};

static double ccl4[121] = {
  1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10, 1.075e-10,
  1.075e-10, 1.075e-10, 1.075e-10, 1.06e-10, 1.024e-10, 9.69e-11,
  8.93e-11, 8.078e-11, 7.213e-11, 6.307e-11, 5.383e-11, 4.49e-11,
  3.609e-11, 2.705e-11, 1.935e-11, 1.385e-11, 8.35e-12, 5.485e-12,
  3.853e-12, 2.22e-12, 5.875e-13, 3.445e-13, 1.015e-13, 6.075e-14,
  4.383e-14, 2.692e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14, 1e-14,
  1e-14, 1e-14, 1e-14
};

static double ch4[121] = {
  1.864e-06, 1.835e-06, 1.819e-06, 1.805e-06, 1.796e-06, 1.788e-06,
  1.782e-06, 1.776e-06, 1.769e-06, 1.761e-06, 1.749e-06, 1.734e-06,
  1.716e-06, 1.692e-06, 1.654e-06, 1.61e-06, 1.567e-06, 1.502e-06,
  1.433e-06, 1.371e-06, 1.323e-06, 1.277e-06, 1.232e-06, 1.188e-06,
  1.147e-06, 1.108e-06, 1.07e-06, 1.027e-06, 9.854e-07, 9.416e-07,
  8.933e-07, 8.478e-07, 7.988e-07, 7.515e-07, 7.07e-07, 6.64e-07,
  6.239e-07, 5.864e-07, 5.512e-07, 5.184e-07, 4.87e-07, 4.571e-07,
  4.296e-07, 4.04e-07, 3.802e-07, 3.578e-07, 3.383e-07, 3.203e-07,
  3.032e-07, 2.889e-07, 2.76e-07, 2.635e-07, 2.519e-07, 2.409e-07,
  2.302e-07, 2.219e-07, 2.144e-07, 2.071e-07, 1.999e-07, 1.93e-07,
  1.862e-07, 1.795e-07, 1.731e-07, 1.668e-07, 1.607e-07, 1.548e-07,
  1.49e-07, 1.434e-07, 1.38e-07, 1.328e-07, 1.277e-07, 1.227e-07,
  1.18e-07, 1.134e-07, 1.089e-07, 1.046e-07, 1.004e-07, 9.635e-08,
  9.245e-08, 8.867e-08, 8.502e-08, 8.15e-08, 7.809e-08, 7.48e-08,
  7.159e-08, 6.849e-08, 6.55e-08, 6.262e-08, 5.98e-08, 5.708e-08,
  5.448e-08, 5.194e-08, 4.951e-08, 4.72e-08, 4.5e-08, 4.291e-08,
  4.093e-08, 3.905e-08, 3.729e-08, 3.563e-08, 3.408e-08, 3.265e-08,
  3.128e-08, 2.996e-08, 2.87e-08, 2.76e-08, 2.657e-08, 2.558e-08,
  2.467e-08, 2.385e-08, 2.307e-08, 2.234e-08, 2.168e-08, 2.108e-08,
    2.05e-08, 1.998e-08, 1.947e-08, 1.902e-08, 1.86e-08, 1.819e-08,
    1.782e-08
  };

  static double clo[121] = {
    7.419e-15, 1.061e-14, 1.518e-14, 2.195e-14, 3.175e-14, 4.666e-14,
    6.872e-14, 1.03e-13, 1.553e-13, 2.375e-13, 3.664e-13, 5.684e-13,
    8.915e-13, 1.402e-12, 2.269e-12, 4.125e-12, 7.501e-12, 1.257e-11,
    2.048e-11, 3.338e-11, 5.44e-11, 8.846e-11, 1.008e-10, 1.082e-10,
    1.157e-10, 1.232e-10, 1.312e-10, 1.539e-10, 1.822e-10, 2.118e-10,
    2.387e-10, 2.687e-10, 2.875e-10, 3.031e-10, 3.23e-10, 3.648e-10,
    4.117e-10, 4.477e-10, 4.633e-10, 4.794e-10, 4.95e-10, 5.104e-10,
    5.259e-10, 5.062e-10, 4.742e-10, 4.443e-10, 4.051e-10, 3.659e-10,
    3.305e-10, 2.911e-10, 2.54e-10, 2.215e-10, 1.927e-10, 1.675e-10,
    1.452e-10, 1.259e-10, 1.09e-10, 9.416e-11, 8.119e-11, 6.991e-11,
    6.015e-11, 5.163e-11, 4.43e-11, 3.789e-11, 3.24e-11, 2.769e-11,
    2.361e-11, 2.011e-11, 1.71e-11, 1.453e-11, 1.233e-11, 1.045e-11,
    8.851e-12, 7.48e-12, 6.316e-12, 5.326e-12, 4.487e-12, 3.778e-12,
    3.176e-12, 2.665e-12, 2.234e-12, 1.87e-12, 1.563e-12, 1.304e-12,
    1.085e-12, 9.007e-13, 7.468e-13, 6.179e-13, 5.092e-13, 4.188e-13,
    3.442e-13, 2.816e-13, 2.304e-13, 1.885e-13, 1.542e-13, 1.263e-13,
    1.035e-13, 8.5e-14, 7.004e-14, 5.783e-14, 4.795e-14, 4.007e-14,
    3.345e-14, 2.792e-14, 2.33e-14, 1.978e-14, 1.686e-14, 1.438e-14,
    1.234e-14, 1.07e-14, 9.312e-15, 8.131e-15, 7.164e-15, 6.367e-15,
    5.67e-15, 5.088e-15, 4.565e-15, 4.138e-15, 3.769e-15, 3.432e-15,
    3.148e-15
  };

  static double clono2[121] = {
    1.011e-13, 1.515e-13, 2.272e-13, 3.446e-13, 5.231e-13, 8.085e-13,
    1.253e-12, 1.979e-12, 3.149e-12, 5.092e-12, 8.312e-12, 1.366e-11,
    2.272e-11, 3.791e-11, 6.209e-11, 9.101e-11, 1.334e-10, 1.951e-10,
    2.853e-10, 3.94e-10, 4.771e-10, 5.771e-10, 6.675e-10, 7.665e-10,
    8.504e-10, 8.924e-10, 9.363e-10, 8.923e-10, 8.411e-10, 7.646e-10,
    6.525e-10, 5.576e-10, 4.398e-10, 3.403e-10, 2.612e-10, 1.915e-10,
    1.407e-10, 1.028e-10, 7.455e-11, 5.42e-11, 3.708e-11, 2.438e-11,
    1.618e-11, 1.075e-11, 7.17e-12, 4.784e-12, 3.205e-12, 2.147e-12,
    1.44e-12, 9.654e-13, 6.469e-13, 4.332e-13, 2.891e-13, 1.926e-13,
    1.274e-13, 8.422e-14, 5.547e-14, 3.636e-14, 2.368e-14, 1.536e-14,
    9.937e-15, 6.39e-15, 4.101e-15, 2.61e-15, 1.659e-15, 1.052e-15,
    6.638e-16, 4.172e-16, 2.61e-16, 1.63e-16, 1.013e-16, 6.275e-17,
    3.879e-17, 2.383e-17, 1.461e-17, 8.918e-18, 5.43e-18, 3.301e-18,
    1.997e-18, 1.203e-18, 7.216e-19, 4.311e-19, 2.564e-19, 1.519e-19,
    8.911e-20, 5.203e-20, 3.026e-20, 1.748e-20, 9.99e-21, 5.673e-21,
    3.215e-21, 1.799e-21, 1.006e-21, 5.628e-22, 3.146e-22, 1.766e-22,
    9.94e-23, 5.614e-23, 3.206e-23, 1.841e-23, 1.071e-23, 6.366e-24,
    3.776e-24, 2.238e-24, 1.326e-24, 8.253e-25, 5.201e-25, 3.279e-25,
    2.108e-25, 1.395e-25, 9.326e-26, 6.299e-26, 4.365e-26, 3.104e-26,
    2.219e-26, 1.621e-26, 1.185e-26, 8.92e-27, 6.804e-27, 5.191e-27,
    4.041e-27
  };

  static double co[121] = {
    1.907e-07, 1.553e-07, 1.362e-07, 1.216e-07, 1.114e-07, 1.036e-07,
    9.737e-08, 9.152e-08, 8.559e-08, 7.966e-08, 7.277e-08, 6.615e-08,
    5.884e-08, 5.22e-08, 4.699e-08, 4.284e-08, 3.776e-08, 3.274e-08,
    2.845e-08, 2.479e-08, 2.246e-08, 2.054e-08, 1.991e-08, 1.951e-08,
    1.94e-08, 2.009e-08, 2.1e-08, 2.201e-08, 2.322e-08, 2.45e-08,
    2.602e-08, 2.73e-08, 2.867e-08, 2.998e-08, 3.135e-08, 3.255e-08,
    3.352e-08, 3.426e-08, 3.484e-08, 3.53e-08, 3.593e-08, 3.671e-08,
    3.759e-08, 3.945e-08, 4.192e-08, 4.49e-08, 5.03e-08, 5.703e-08,
    6.538e-08, 7.878e-08, 9.644e-08, 1.196e-07, 1.498e-07, 1.904e-07,
    2.422e-07, 3.055e-07, 3.804e-07, 4.747e-07, 5.899e-07, 7.272e-07,
    8.91e-07, 1.071e-06, 1.296e-06, 1.546e-06, 1.823e-06, 2.135e-06,
    2.44e-06, 2.714e-06, 2.967e-06, 3.189e-06, 3.391e-06, 3.58e-06,
    3.773e-06, 4.022e-06, 4.346e-06, 4.749e-06, 5.199e-06, 5.668e-06,
    6.157e-06, 6.688e-06, 7.254e-06, 7.867e-06, 8.539e-06, 9.26e-06,
    1.009e-05, 1.119e-05, 1.228e-05, 1.365e-05, 1.506e-05, 1.641e-05,
    1.784e-05, 1.952e-05, 2.132e-05, 2.323e-05, 2.531e-05, 2.754e-05,
    3.047e-05, 3.459e-05, 3.922e-05, 4.439e-05, 4.825e-05, 5.077e-05,
    5.34e-05, 5.618e-05, 5.909e-05, 6.207e-05, 6.519e-05, 6.845e-05,
    6.819e-05, 6.726e-05, 6.622e-05, 6.512e-05, 6.671e-05, 6.862e-05,
    7.048e-05, 7.264e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05, 7.3e-05
  };

  static double cof2[121] = {
    7.5e-14, 1.055e-13, 1.485e-13, 2.111e-13, 3.001e-13, 4.333e-13,
    6.269e-13, 9.221e-13, 1.364e-12, 2.046e-12, 3.093e-12, 4.703e-12,
    7.225e-12, 1.113e-11, 1.66e-11, 2.088e-11, 2.626e-11, 3.433e-11,
    4.549e-11, 5.886e-11, 7.21e-11, 8.824e-11, 1.015e-10, 1.155e-10,
    1.288e-10, 1.388e-10, 1.497e-10, 1.554e-10, 1.606e-10, 1.639e-10,
    1.64e-10, 1.64e-10, 1.596e-10, 1.542e-10, 1.482e-10, 1.382e-10,
    1.289e-10, 1.198e-10, 1.109e-10, 1.026e-10, 9.484e-11, 8.75e-11,
    8.086e-11, 7.49e-11, 6.948e-11, 6.446e-11, 5.961e-11, 5.505e-11,
    5.085e-11, 4.586e-11, 4.1e-11, 3.665e-11, 3.235e-11, 2.842e-11,
    2.491e-11, 2.11e-11, 1.769e-11, 1.479e-11, 1.197e-11, 9.631e-12,
    7.74e-12, 6.201e-12, 4.963e-12, 3.956e-12, 3.151e-12, 2.507e-12,
    1.99e-12, 1.576e-12, 1.245e-12, 9.83e-13, 7.742e-13, 6.088e-13,
    4.782e-13, 3.745e-13, 2.929e-13, 2.286e-13, 1.782e-13, 1.388e-13,
    1.079e-13, 8.362e-14, 6.471e-14, 4.996e-14, 3.85e-14, 2.96e-14,
    2.265e-14, 1.729e-14, 1.317e-14, 9.998e-15, 7.549e-15, 5.683e-15,
    4.273e-15, 3.193e-15, 2.385e-15, 1.782e-15, 1.331e-15, 9.957e-16,
    7.461e-16, 5.601e-16, 4.228e-16, 3.201e-16, 2.438e-16, 1.878e-16,
    1.445e-16, 1.111e-16, 8.544e-17, 6.734e-17, 5.341e-17, 4.237e-17,
    3.394e-17, 2.759e-17, 2.254e-17, 1.851e-17, 1.54e-17, 1.297e-17,
    1.096e-17, 9.365e-18, 8e-18, 6.938e-18, 6.056e-18, 5.287e-18,
    4.662e-18
  };

  static double f11[121] = {
    2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10,
    2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.65e-10, 2.635e-10, 2.536e-10,
    2.44e-10, 2.348e-10, 2.258e-10, 2.153e-10, 2.046e-10, 1.929e-10,
    1.782e-10, 1.648e-10, 1.463e-10, 1.291e-10, 1.1e-10, 8.874e-11,
    7.165e-11, 5.201e-11, 3.744e-11, 2.577e-11, 1.64e-11, 1.048e-11,
    5.993e-12, 3.345e-12, 1.839e-12, 9.264e-13, 4.688e-13, 2.329e-13,
    1.129e-13, 5.505e-14, 2.825e-14, 1.492e-14, 7.997e-15, 5.384e-15,
    3.988e-15, 2.955e-15, 2.196e-15, 1.632e-15, 1.214e-15, 9.025e-16,
    6.708e-16, 4.984e-16, 3.693e-16, 2.733e-16, 2.013e-16, 1.481e-16,
    1.087e-16, 7.945e-17, 5.782e-17, 4.195e-17, 3.038e-17, 2.19e-17,
    1.577e-17, 1.128e-17, 8.063e-18, 5.753e-18, 4.09e-18, 2.899e-18,
    2.048e-18, 1.444e-18, 1.015e-18, 7.12e-19, 4.985e-19, 3.474e-19,
    2.417e-19, 1.677e-19, 1.161e-19, 8.029e-20, 5.533e-20, 3.799e-20,
    2.602e-20, 1.776e-20, 1.209e-20, 8.202e-21, 5.522e-21, 3.707e-21,
    2.48e-21, 1.652e-21, 1.091e-21, 7.174e-22, 4.709e-22, 3.063e-22,
    1.991e-22, 1.294e-22, 8.412e-23, 5.483e-23, 3.581e-23, 2.345e-23,
    1.548e-23, 1.027e-23, 6.869e-24, 4.673e-24, 3.173e-24, 2.153e-24,
    1.461e-24, 1.028e-24, 7.302e-25, 5.188e-25, 3.739e-25, 2.753e-25,
    2.043e-25, 1.528e-25, 1.164e-25, 9.041e-26, 7.051e-26, 5.587e-26,
    4.428e-26, 3.588e-26, 2.936e-26, 2.402e-26, 1.995e-26
  };

  static double f12[121] = {
    5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10,
    5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.45e-10, 5.429e-10, 5.291e-10,
    5.155e-10, 5.022e-10, 4.893e-10, 4.772e-10, 4.655e-10, 4.497e-10,
    4.249e-10, 4.015e-10, 3.632e-10, 3.261e-10, 2.858e-10, 2.408e-10,
    2.03e-10, 1.685e-10, 1.4e-10, 1.163e-10, 9.65e-11, 8.02e-11, 6.705e-11,
    5.624e-11, 4.764e-11, 4.249e-11, 3.792e-11, 3.315e-11, 2.819e-11,
    2.4e-11, 1.999e-11, 1.64e-11, 1.352e-11, 1.14e-11, 9.714e-12,
    8.28e-12, 7.176e-12, 6.251e-12, 5.446e-12, 4.72e-12, 4.081e-12,
    3.528e-12, 3.08e-12, 2.699e-12, 2.359e-12, 2.111e-12, 1.901e-12,
    1.709e-12, 1.534e-12, 1.376e-12, 1.233e-12, 1.103e-12, 9.869e-13,
    8.808e-13, 7.859e-13, 7.008e-13, 6.241e-13, 5.553e-13, 4.935e-13,
    4.383e-13, 3.889e-13, 3.447e-13, 3.054e-13, 2.702e-13, 2.389e-13,
    2.11e-13, 1.862e-13, 1.643e-13, 1.448e-13, 1.274e-13, 1.121e-13,
    9.844e-14, 8.638e-14, 7.572e-14, 6.62e-14, 5.782e-14, 5.045e-14,
    4.394e-14, 3.817e-14, 3.311e-14, 2.87e-14, 2.48e-14, 2.142e-14,
    1.851e-14, 1.599e-14, 1.383e-14, 1.196e-14, 1.036e-14, 9e-15,
    7.828e-15, 6.829e-15, 5.992e-15, 5.254e-15, 4.606e-15, 4.037e-15,
    3.583e-15, 3.19e-15, 2.841e-15, 2.542e-15, 2.291e-15, 2.07e-15,
    1.875e-15, 1.71e-15, 1.57e-15, 1.442e-15, 1.333e-15, 1.232e-15,
    1.147e-15, 1.071e-15, 1.001e-15, 9.396e-16
  };

  static double f14[121] = {
    9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 9e-11,
    9e-11, 9e-11, 9e-11, 9e-11, 9e-11, 8.91e-11, 8.73e-11, 8.46e-11,
    8.19e-11, 7.92e-11, 7.74e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11,
    7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11, 7.65e-11
  };

  static double f22[121] = {
    1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10, 1.4e-10,
    1.4e-10, 1.4e-10, 1.4e-10, 1.372e-10, 1.317e-10, 1.235e-10, 1.153e-10,
    1.075e-10, 1.002e-10, 9.332e-11, 8.738e-11, 8.194e-11, 7.7e-11,
    7.165e-11, 6.753e-11, 6.341e-11, 5.971e-11, 5.6e-11, 5.229e-11,
    4.859e-11, 4.488e-11, 4.118e-11, 3.83e-11, 3.568e-11, 3.308e-11,
    3.047e-11, 2.82e-11, 2.594e-11, 2.409e-11, 2.237e-11, 2.065e-11,
    1.894e-11, 1.771e-11, 1.647e-11, 1.532e-11, 1.416e-11, 1.332e-11,
    1.246e-11, 1.161e-11, 1.087e-11, 1.017e-11, 9.471e-12, 8.853e-12,
  8.235e-12, 7.741e-12, 7.247e-12, 6.836e-12, 6.506e-12, 6.176e-12,
  5.913e-12, 5.65e-12, 5.419e-12, 5.221e-12, 5.024e-12, 4.859e-12,
  4.694e-12, 4.546e-12, 4.414e-12, 4.282e-12, 4.15e-12, 4.019e-12,
  3.903e-12, 3.805e-12, 3.706e-12, 3.607e-12, 3.508e-12, 3.41e-12,
  3.31e-12, 3.212e-12, 3.129e-12, 3.047e-12, 2.964e-12, 2.882e-12,
  2.8e-12, 2.734e-12, 2.668e-12, 2.602e-12, 2.537e-12, 2.471e-12,
  2.421e-12, 2.372e-12, 2.322e-12, 2.273e-12, 2.224e-12, 2.182e-12,
  2.141e-12, 2.1e-12, 2.059e-12, 2.018e-12, 1.977e-12, 1.935e-12,
  1.894e-12, 1.853e-12, 1.812e-12, 1.77e-12, 1.73e-12, 1.688e-12,
  1.647e-12, 1.606e-12, 1.565e-12, 1.524e-12, 1.483e-12, 1.441e-12,
  1.4e-12, 1.359e-12, 1.317e-12, 1.276e-12, 1.235e-12, 1.194e-12,
  1.153e-12, 1.112e-12, 1.071e-12, 1.029e-12, 9.883e-13
};

static double h2o[121] = {
  0.01166, 0.008269, 0.005742, 0.003845, 0.00277, 0.001897, 0.001272,
  0.000827, 0.000539, 0.0003469, 0.0001579, 3.134e-05, 1.341e-05,
  6.764e-06, 4.498e-06, 3.703e-06, 3.724e-06, 3.899e-06, 4.002e-06,
  4.122e-06, 4.277e-06, 4.438e-06, 4.558e-06, 4.673e-06, 4.763e-06,
  4.809e-06, 4.856e-06, 4.936e-06, 5.021e-06, 5.114e-06, 5.222e-06,
  5.331e-06, 5.414e-06, 5.488e-06, 5.563e-06, 5.633e-06, 5.704e-06,
  5.767e-06, 5.819e-06, 5.872e-06, 5.914e-06, 5.949e-06, 5.984e-06,
  6.015e-06, 6.044e-06, 6.073e-06, 6.104e-06, 6.136e-06, 6.167e-06,
  6.189e-06, 6.208e-06, 6.226e-06, 6.212e-06, 6.185e-06, 6.158e-06,
  6.114e-06, 6.066e-06, 6.018e-06, 5.877e-06, 5.728e-06, 5.582e-06,
  5.437e-06, 5.296e-06, 5.156e-06, 5.02e-06, 4.886e-06, 4.754e-06,
  4.625e-06, 4.498e-06, 4.374e-06, 4.242e-06, 4.096e-06, 3.955e-06,
  3.817e-06, 3.683e-06, 3.491e-06, 3.204e-06, 2.94e-06, 2.696e-06,
  2.47e-06, 2.252e-06, 2.019e-06, 1.808e-06, 1.618e-06, 1.445e-06,
  1.285e-06, 1.105e-06, 9.489e-07, 8.121e-07, 6.938e-07, 5.924e-07,
  5.04e-07, 4.288e-07, 3.648e-07, 3.103e-07, 2.642e-07, 2.252e-07,
  1.921e-07, 1.643e-07, 1.408e-07, 1.211e-07, 1.048e-07, 9.063e-08,
  7.835e-08, 6.774e-08, 5.936e-08, 5.221e-08, 4.592e-08, 4.061e-08,
  3.62e-08, 3.236e-08, 2.902e-08, 2.62e-08, 2.383e-08, 2.171e-08,
  1.989e-08, 1.823e-08, 1.684e-08, 1.562e-08, 1.449e-08, 1.351e-08
};

static double h2o2[121] = {
  1.779e-10, 7.938e-10, 8.953e-10, 8.032e-10, 6.564e-10, 5.159e-10,
  4.003e-10, 3.026e-10, 2.222e-10, 1.58e-10, 1.044e-10, 6.605e-11,
  3.413e-11, 1.453e-11, 1.062e-11, 1.009e-11, 9.597e-12, 1.175e-11,
  1.572e-11, 2.091e-11, 2.746e-11, 3.603e-11, 4.791e-11, 6.387e-11,
  8.239e-11, 1.007e-10, 1.23e-10, 1.363e-10, 1.489e-10, 1.585e-10,
  1.608e-10, 1.632e-10, 1.576e-10, 1.502e-10, 1.423e-10, 1.302e-10,
  1.192e-10, 1.085e-10, 9.795e-11, 8.854e-11, 8.057e-11, 7.36e-11,
  6.736e-11, 6.362e-11, 6.087e-11, 5.825e-11, 5.623e-11, 5.443e-11,
  5.27e-11, 5.098e-11, 4.931e-11, 4.769e-11, 4.611e-11, 4.458e-11,
  4.308e-11, 4.102e-11, 3.887e-11, 3.682e-11, 3.521e-11, 3.369e-11,
  3.224e-11, 3.082e-11, 2.946e-11, 2.814e-11, 2.687e-11, 2.566e-11,
  2.449e-11, 2.336e-11, 2.227e-11, 2.123e-11, 2.023e-11, 1.927e-11,
  1.835e-11, 1.746e-11, 1.661e-11, 1.58e-11, 1.502e-11, 1.428e-11,
  1.357e-11, 1.289e-11, 1.224e-11, 1.161e-11, 1.102e-11, 1.045e-11,
  9.895e-12, 9.369e-12, 8.866e-12, 8.386e-12, 7.922e-12, 7.479e-12,
  7.06e-12, 6.656e-12, 6.274e-12, 5.914e-12, 5.575e-12, 5.257e-12,
  4.959e-12, 4.679e-12, 4.42e-12, 4.178e-12, 3.954e-12, 3.75e-12,
  3.557e-12, 3.372e-12, 3.198e-12, 3.047e-12, 2.908e-12, 2.775e-12,
  2.653e-12, 2.544e-12, 2.442e-12, 2.346e-12, 2.26e-12, 2.183e-12,
  2.11e-12, 2.044e-12, 1.98e-12, 1.924e-12, 1.871e-12, 1.821e-12,
  1.775e-12
};

static double hcn[121] = {
  5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10,
  5.5e-10, 5.5e-10, 5.5e-10, 5.5e-10, 5.498e-10, 5.495e-10, 5.493e-10,
  5.49e-10, 5.488e-10, 4.717e-10, 3.946e-10, 3.174e-10, 2.4e-10,
  1.626e-10, 1.619e-10, 1.612e-10, 1.602e-10, 1.593e-10, 1.582e-10,
  1.572e-10, 1.56e-10, 1.549e-10, 1.539e-10, 1.53e-10, 1.519e-10,
  1.506e-10, 1.487e-10, 1.467e-10, 1.449e-10, 1.43e-10, 1.413e-10,
  1.397e-10, 1.382e-10, 1.368e-10, 1.354e-10, 1.337e-10, 1.315e-10,
  1.292e-10, 1.267e-10, 1.241e-10, 1.215e-10, 1.19e-10, 1.165e-10,
  1.141e-10, 1.118e-10, 1.096e-10, 1.072e-10, 1.047e-10, 1.021e-10,
  9.968e-11, 9.739e-11, 9.539e-11, 9.339e-11, 9.135e-11, 8.898e-11,
  8.664e-11, 8.439e-11, 8.249e-11, 8.075e-11, 7.904e-11, 7.735e-11,
  7.565e-11, 7.399e-11, 7.245e-11, 7.109e-11, 6.982e-11, 6.863e-11,
  6.755e-11, 6.657e-11, 6.587e-11, 6.527e-11, 6.476e-11, 6.428e-11,
  6.382e-11, 6.343e-11, 6.307e-11, 6.272e-11, 6.238e-11, 6.205e-11,
  6.17e-11, 6.137e-11, 6.102e-11, 6.072e-11, 6.046e-11, 6.03e-11,
  6.018e-11, 6.01e-11, 6.001e-11, 5.992e-11, 5.984e-11, 5.975e-11,
  5.967e-11, 5.958e-11, 5.95e-11, 5.941e-11, 5.933e-11, 5.925e-11,
  5.916e-11, 5.908e-11, 5.899e-11, 5.891e-11, 5.883e-11, 5.874e-11,
  5.866e-11, 5.858e-11, 5.85e-11, 5.841e-11, 5.833e-11, 5.825e-11,
  5.817e-11, 5.808e-11, 5.8e-11, 5.792e-11, 5.784e-11
};

static double hno3[121] = {
  1.809e-10, 7.234e-10, 5.899e-10, 4.342e-10, 3.277e-10, 2.661e-10,
  2.35e-10, 2.267e-10, 2.389e-10, 2.651e-10, 3.255e-10, 4.099e-10,
    5.42e-10, 6.978e-10, 8.807e-10, 1.112e-09, 1.405e-09, 2.04e-09,
    3.111e-09, 4.5e-09, 5.762e-09, 7.37e-09, 7.852e-09, 8.109e-09,
    8.067e-09, 7.554e-09, 7.076e-09, 6.268e-09, 5.524e-09, 4.749e-09,
    3.909e-09, 3.223e-09, 2.517e-09, 1.942e-09, 1.493e-09, 1.122e-09,
    8.449e-10, 6.361e-10, 4.787e-10, 3.611e-10, 2.804e-10, 2.215e-10,
    1.758e-10, 1.441e-10, 1.197e-10, 9.953e-11, 8.505e-11, 7.334e-11,
    6.325e-11, 5.625e-11, 5.058e-11, 4.548e-11, 4.122e-11, 3.748e-11,
    3.402e-11, 3.088e-11, 2.8e-11, 2.536e-11, 2.293e-11, 2.072e-11,
    1.871e-11, 1.687e-11, 1.52e-11, 1.368e-11, 1.23e-11, 1.105e-11,
    9.922e-12, 8.898e-12, 7.972e-12, 7.139e-12, 6.385e-12, 5.708e-12,
    5.099e-12, 4.549e-12, 4.056e-12, 3.613e-12, 3.216e-12, 2.862e-12,
    2.544e-12, 2.259e-12, 2.004e-12, 1.776e-12, 1.572e-12, 1.391e-12,
    1.227e-12, 1.082e-12, 9.528e-13, 8.379e-13, 7.349e-13, 6.436e-13,
    5.634e-13, 4.917e-13, 4.291e-13, 3.745e-13, 3.267e-13, 2.854e-13,
    2.494e-13, 2.181e-13, 1.913e-13, 1.68e-13, 1.479e-13, 1.31e-13,
    1.159e-13, 1.025e-13, 9.067e-14, 8.113e-14, 7.281e-14, 6.535e-14,
    5.892e-14, 5.348e-14, 4.867e-14, 4.439e-14, 4.073e-14, 3.76e-14,
    3.476e-14, 3.229e-14, 3e-14, 2.807e-14, 2.635e-14, 2.473e-14,
    2.332e-14
  };

  static double hno4[121] = {
    6.118e-12, 3.594e-12, 2.807e-12, 3.04e-12, 4.458e-12, 7.986e-12,
    1.509e-11, 2.661e-11, 3.738e-11, 4.652e-11, 4.429e-11, 3.992e-11,
    3.347e-11, 3.005e-11, 3.173e-11, 4.055e-11, 5.812e-11, 8.489e-11,
    1.19e-10, 1.482e-10, 1.766e-10, 2.103e-10, 2.35e-10, 2.598e-10,
    2.801e-10, 2.899e-10, 3e-10, 2.817e-10, 2.617e-10, 2.332e-10,
    1.933e-10, 1.605e-10, 1.232e-10, 9.285e-11, 6.941e-11, 4.951e-11,
    3.539e-11, 2.402e-11, 1.522e-11, 9.676e-12, 6.056e-12, 3.745e-12,
    2.34e-12, 1.463e-12, 9.186e-13, 5.769e-13, 3.322e-13, 1.853e-13,
    1.035e-13, 7.173e-14, 5.382e-14, 4.036e-14, 3.401e-14, 2.997e-14,
    2.635e-14, 2.316e-14, 2.034e-14, 1.783e-14, 1.56e-14, 1.363e-14,
    1.19e-14, 1.037e-14, 9.032e-15, 7.846e-15, 6.813e-15, 5.912e-15,
    5.121e-15, 4.431e-15, 3.829e-15, 3.306e-15, 2.851e-15, 2.456e-15,
    2.114e-15, 1.816e-15, 1.559e-15, 1.337e-15, 1.146e-15, 9.811e-16,
    8.389e-16, 7.162e-16, 6.109e-16, 5.203e-16, 4.425e-16, 3.76e-16,
    3.184e-16, 2.692e-16, 2.274e-16, 1.917e-16, 1.61e-16, 1.35e-16,
    1.131e-16, 9.437e-17, 7.874e-17, 6.57e-17, 5.481e-17, 4.579e-17,
    3.828e-17, 3.204e-17, 2.691e-17, 2.264e-17, 1.912e-17, 1.626e-17,
    1.382e-17, 1.174e-17, 9.972e-18, 8.603e-18, 7.45e-18, 6.453e-18,
    5.623e-18, 4.944e-18, 4.361e-18, 3.859e-18, 3.443e-18, 3.096e-18,
    2.788e-18, 2.528e-18, 2.293e-18, 2.099e-18, 1.929e-18, 1.773e-18,
    1.64e-18
  };

  static double hocl[121] = {
    1.056e-12, 1.194e-12, 1.35e-12, 1.531e-12, 1.737e-12, 1.982e-12,
    2.263e-12, 2.599e-12, 2.991e-12, 3.459e-12, 4.012e-12, 4.662e-12,
    5.438e-12, 6.35e-12, 7.425e-12, 8.686e-12, 1.016e-11, 1.188e-11,
    1.389e-11, 1.659e-11, 2.087e-11, 2.621e-11, 3.265e-11, 4.064e-11,
    4.859e-11, 5.441e-11, 6.09e-11, 6.373e-11, 6.611e-11, 6.94e-11,
    7.44e-11, 7.97e-11, 8.775e-11, 9.722e-11, 1.064e-10, 1.089e-10,
    1.114e-10, 1.106e-10, 1.053e-10, 1.004e-10, 9.006e-11, 7.778e-11,
    6.739e-11, 5.636e-11, 4.655e-11, 3.845e-11, 3.042e-11, 2.368e-11,
    1.845e-11, 1.442e-11, 1.127e-11, 8.814e-12, 6.544e-12, 4.763e-12,
    3.449e-12, 2.612e-12, 1.999e-12, 1.526e-12, 1.16e-12, 8.793e-13,
    6.655e-13, 5.017e-13, 3.778e-13, 2.829e-13, 2.117e-13, 1.582e-13,
    1.178e-13, 8.755e-14, 6.486e-14, 4.799e-14, 3.54e-14, 2.606e-14,
    1.916e-14, 1.403e-14, 1.026e-14, 7.48e-15, 5.446e-15, 3.961e-15,
    2.872e-15, 2.076e-15, 1.498e-15, 1.077e-15, 7.726e-16, 5.528e-16,
    3.929e-16, 2.785e-16, 1.969e-16, 1.386e-16, 9.69e-17, 6.747e-17,
    4.692e-17, 3.236e-17, 2.232e-17, 1.539e-17, 1.061e-17, 7.332e-18,
    5.076e-18, 3.522e-18, 2.461e-18, 1.726e-18, 1.22e-18, 8.75e-19,
    6.264e-19, 4.482e-19, 3.207e-19, 2.368e-19, 1.762e-19, 1.312e-19,
    9.891e-20, 7.595e-20, 5.87e-20, 4.567e-20, 3.612e-20, 2.904e-20,
    2.343e-20, 1.917e-20, 1.568e-20, 1.308e-20, 1.1e-20, 9.25e-21,
    7.881e-21
  };

  static double n2o[121] = {
    3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07, 3.17e-07,
    3.17e-07, 3.17e-07, 3.17e-07, 3.124e-07, 3.077e-07, 3.03e-07,
    2.984e-07, 2.938e-07, 2.892e-07, 2.847e-07, 2.779e-07, 2.705e-07,
    2.631e-07, 2.557e-07, 2.484e-07, 2.345e-07, 2.201e-07, 2.01e-07,
    1.754e-07, 1.532e-07, 1.329e-07, 1.154e-07, 1.003e-07, 8.735e-08,
    7.617e-08, 6.512e-08, 5.547e-08, 4.709e-08, 3.915e-08, 3.259e-08,
    2.738e-08, 2.327e-08, 1.98e-08, 1.711e-08, 1.493e-08, 1.306e-08,
    1.165e-08, 1.049e-08, 9.439e-09, 8.375e-09, 7.391e-09, 6.525e-09,
    5.759e-09, 5.083e-09, 4.485e-09, 3.953e-09, 3.601e-09, 3.27e-09,
    2.975e-09, 2.757e-09, 2.556e-09, 2.37e-09, 2.195e-09, 2.032e-09,
    1.912e-09, 1.79e-09, 1.679e-09, 1.572e-09, 1.482e-09, 1.402e-09,
    1.326e-09, 1.254e-09, 1.187e-09, 1.127e-09, 1.071e-09, 1.02e-09,
    9.673e-10, 9.193e-10, 8.752e-10, 8.379e-10, 8.017e-10, 7.66e-10,
    7.319e-10, 7.004e-10, 6.721e-10, 6.459e-10, 6.199e-10, 5.942e-10,
    5.703e-10, 5.488e-10, 5.283e-10, 5.082e-10, 4.877e-10, 4.696e-10,
    4.52e-10, 4.355e-10, 4.198e-10, 4.039e-10, 3.888e-10, 3.754e-10,
    3.624e-10, 3.499e-10, 3.381e-10, 3.267e-10, 3.163e-10, 3.058e-10,
  2.959e-10, 2.864e-10, 2.77e-10, 2.686e-10, 2.604e-10, 2.534e-10,
  2.462e-10, 2.386e-10, 2.318e-10, 2.247e-10, 2.189e-10, 2.133e-10,
  2.071e-10, 2.014e-10, 1.955e-10, 1.908e-10, 1.86e-10, 1.817e-10
};

static double n2o5[121] = {
  1.231e-11, 3.035e-12, 1.702e-12, 9.877e-13, 8.081e-13, 9.039e-13,
  1.169e-12, 1.474e-12, 1.651e-12, 1.795e-12, 1.998e-12, 2.543e-12,
  4.398e-12, 7.698e-12, 1.28e-11, 2.131e-11, 3.548e-11, 5.894e-11,
  7.645e-11, 1.089e-10, 1.391e-10, 1.886e-10, 2.386e-10, 2.986e-10,
  3.487e-10, 3.994e-10, 4.5e-10, 4.6e-10, 4.591e-10, 4.1e-10, 3.488e-10,
  2.846e-10, 2.287e-10, 1.696e-10, 1.011e-10, 6.428e-11, 4.324e-11,
  2.225e-11, 6.214e-12, 3.608e-12, 8.793e-13, 4.491e-13, 1.04e-13,
  6.1e-14, 3.436e-14, 6.671e-15, 1.171e-15, 5.848e-16, 1.212e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16, 1e-16,
  1e-16, 1e-16
};

static double nh3[121] = {
  1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
  1e-10, 1e-10, 1e-10, 1e-10, 9.444e-11, 8.488e-11, 7.241e-11, 5.785e-11,
  4.178e-11, 3.018e-11, 2.18e-11, 1.574e-11, 1.137e-11, 8.211e-12,
  5.973e-12, 4.327e-12, 3.118e-12, 2.234e-12, 1.573e-12, 1.04e-12,
  6.762e-13, 4.202e-13, 2.406e-13, 1.335e-13, 6.938e-14, 3.105e-14,
  1.609e-14, 1.033e-14, 6.432e-15, 4.031e-15, 2.555e-15, 1.656e-15,
  1.115e-15, 7.904e-16, 5.63e-16, 4.048e-16, 2.876e-16, 2.004e-16,
  1.356e-16, 9.237e-17, 6.235e-17, 4.223e-17, 3.009e-17, 2.328e-17,
  2.002e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17, 1.914e-17,
  1.914e-17
};

static double no[121] = {
  2.586e-10, 4.143e-11, 1.566e-11, 9.591e-12, 8.088e-12, 8.462e-12,
  1.013e-11, 1.328e-11, 1.855e-11, 2.678e-11, 3.926e-11, 5.464e-11,
  7.012e-11, 8.912e-11, 1.127e-10, 1.347e-10, 1.498e-10, 1.544e-10,
  1.602e-10, 1.824e-10, 2.078e-10, 2.366e-10, 2.691e-10, 5.141e-10,
  8.259e-10, 1.254e-09, 1.849e-09, 2.473e-09, 3.294e-09, 4.16e-09,
  5.095e-09, 6.11e-09, 6.93e-09, 7.888e-09, 8.903e-09, 9.713e-09,
  1.052e-08, 1.115e-08, 1.173e-08, 1.21e-08, 1.228e-08, 1.239e-08,
  1.231e-08, 1.213e-08, 1.192e-08, 1.138e-08, 1.085e-08, 1.008e-08,
  9.224e-09, 8.389e-09, 7.262e-09, 6.278e-09, 5.335e-09, 4.388e-09,
  3.589e-09, 2.761e-09, 2.129e-09, 1.633e-09, 1.243e-09, 9.681e-10,
  8.355e-10, 7.665e-10, 7.442e-10, 8.584e-10, 9.732e-10, 1.063e-09,
  1.163e-09, 1.286e-09, 1.472e-09, 1.707e-09, 2.032e-09, 2.474e-09,
  2.977e-09, 3.506e-09, 4.102e-09, 5.013e-09, 6.493e-09, 8.414e-09,
  1.077e-08, 1.367e-08, 1.777e-08, 2.625e-08, 3.926e-08, 5.545e-08,
  7.195e-08, 9.464e-08, 1.404e-07, 2.183e-07, 3.329e-07, 4.535e-07,
  6.158e-07, 8.187e-07, 1.075e-06, 1.422e-06, 1.979e-06, 2.71e-06,
  3.58e-06, 4.573e-06, 5.951e-06, 7.999e-06, 1.072e-05, 1.372e-05,
  1.697e-05, 2.112e-05, 2.643e-05, 3.288e-05, 3.994e-05, 4.794e-05,
  5.606e-05, 6.383e-05, 7.286e-05, 8.156e-05, 8.883e-05, 9.469e-05,
  9.848e-05, 0.0001023, 0.0001066, 0.0001115, 0.0001145, 0.0001142,
  0.0001133
};

static double no2[121] = {
  3.036e-09, 2.945e-10, 9.982e-11, 5.069e-11, 3.485e-11, 2.982e-11,
  2.947e-11, 3.164e-11, 3.714e-11, 4.586e-11, 6.164e-11, 8.041e-11,
  9.982e-11, 1.283e-10, 1.73e-10, 2.56e-10, 3.909e-10, 5.959e-10,
  9.081e-10, 1.384e-09, 1.788e-09, 2.189e-09, 2.686e-09, 3.091e-09,
  3.49e-09, 3.796e-09, 4.2e-09, 5.103e-09, 6.005e-09, 6.3e-09, 6.706e-09,
  7.07e-09, 7.434e-09, 7.663e-09, 7.788e-09, 7.8e-09, 7.597e-09,
  7.482e-09, 7.227e-09, 6.403e-09, 5.585e-09, 4.606e-09, 3.703e-09,
  2.984e-09, 2.183e-09, 1.48e-09, 8.441e-10, 5.994e-10, 3.799e-10,
  2.751e-10, 1.927e-10, 1.507e-10, 1.102e-10, 6.971e-11, 5.839e-11,
  3.904e-11, 3.087e-11, 2.176e-11, 1.464e-11, 1.209e-11, 8.497e-12,
  6.477e-12, 4.371e-12, 2.914e-12, 2.424e-12, 1.753e-12, 1.35e-12,
  9.417e-13, 6.622e-13, 5.148e-13, 3.841e-13, 3.446e-13, 3.01e-13,
  2.551e-13, 2.151e-13, 1.829e-13, 1.64e-13, 1.475e-13, 1.352e-13,
  1.155e-13, 9.963e-14, 9.771e-14, 9.577e-14, 9.384e-14, 9.186e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14,
  9e-14, 9e-14, 9e-14, 9e-14, 9e-14, 9e-14
};

static double o3[121] = {
  2.218e-08, 3.394e-08, 3.869e-08, 4.219e-08, 4.501e-08, 4.778e-08,
  5.067e-08, 5.402e-08, 5.872e-08, 6.521e-08, 7.709e-08, 9.461e-08,
  1.269e-07, 1.853e-07, 2.723e-07, 3.964e-07, 5.773e-07, 8.2e-07,
  1.155e-06, 1.59e-06, 2.076e-06, 2.706e-06, 3.249e-06, 3.848e-06,
  4.459e-06, 4.986e-06, 5.573e-06, 5.958e-06, 6.328e-06, 6.661e-06,
  6.9e-06, 7.146e-06, 7.276e-06, 7.374e-06, 7.447e-06, 7.383e-06,
  7.321e-06, 7.161e-06, 6.879e-06, 6.611e-06, 6.216e-06, 5.765e-06,
  5.355e-06, 4.905e-06, 4.471e-06, 4.075e-06, 3.728e-06, 3.413e-06,
  3.125e-06, 2.856e-06, 2.607e-06, 2.379e-06, 2.17e-06, 1.978e-06,
  1.8e-06, 1.646e-06, 1.506e-06, 1.376e-06, 1.233e-06, 1.102e-06,
  9.839e-07, 8.771e-07, 7.814e-07, 6.947e-07, 6.102e-07, 5.228e-07,
  4.509e-07, 3.922e-07, 3.501e-07, 3.183e-07, 2.909e-07, 2.686e-07,
  2.476e-07, 2.284e-07, 2.109e-07, 2.003e-07, 2.013e-07, 2.022e-07,
  2.032e-07, 2.042e-07, 2.097e-07, 2.361e-07, 2.656e-07, 2.989e-07,
  3.37e-07, 3.826e-07, 4.489e-07, 5.26e-07, 6.189e-07, 7.312e-07,
  8.496e-07, 8.444e-07, 8.392e-07, 8.339e-07, 8.286e-07, 8.234e-07,
  8.181e-07, 8.129e-07, 8.077e-07, 8.026e-07, 6.918e-07, 5.176e-07,
  3.865e-07, 2.885e-07, 2.156e-07, 1.619e-07, 1.219e-07, 9.161e-08,
  6.972e-08, 5.399e-08, 3.498e-08, 2.111e-08, 1.322e-08, 8.482e-09,
  5.527e-09, 3.423e-09, 2.071e-09, 1.314e-09, 8.529e-10, 5.503e-10,
  3.665e-10
};

static double ocs[121] = {
  6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 6e-10, 5.997e-10,
  5.989e-10, 5.881e-10, 5.765e-10, 5.433e-10, 5.074e-10, 4.567e-10,
  4.067e-10, 3.601e-10, 3.093e-10, 2.619e-10, 2.232e-10, 1.805e-10,
  1.46e-10, 1.187e-10, 8.03e-11, 5.435e-11, 3.686e-11, 2.217e-11,
  1.341e-11, 8.756e-12, 4.511e-12, 2.37e-12, 1.264e-12, 8.28e-13,
  5.263e-13, 3.209e-13, 1.717e-13, 9.068e-14, 4.709e-14, 2.389e-14,
  1.236e-14, 1.127e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14, 1.091e-14,
  1.091e-14, 1.091e-14, 1.091e-14
};

static double sf6[121] = {
  4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12, 4.103e-12,
  4.103e-12, 4.103e-12, 4.103e-12, 4.087e-12, 4.064e-12, 4.023e-12,
  3.988e-12, 3.941e-12, 3.884e-12, 3.755e-12, 3.622e-12, 3.484e-12,
  3.32e-12, 3.144e-12, 2.978e-12, 2.811e-12, 2.653e-12, 2.489e-12,
  2.332e-12, 2.199e-12, 2.089e-12, 2.013e-12, 1.953e-12, 1.898e-12,
  1.859e-12, 1.826e-12, 1.798e-12, 1.776e-12, 1.757e-12, 1.742e-12,
  1.728e-12, 1.717e-12, 1.707e-12, 1.698e-12, 1.691e-12, 1.685e-12,
  1.679e-12, 1.675e-12, 1.671e-12, 1.668e-12, 1.665e-12, 1.663e-12,
  1.661e-12, 1.659e-12, 1.658e-12, 1.657e-12, 1.656e-12, 1.655e-12,
  1.654e-12, 1.653e-12, 1.653e-12, 1.652e-12, 1.652e-12, 1.652e-12,
  1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12, 1.651e-12,
  1.651e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12,
  1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12, 1.65e-12
};

static double so2[121] = {
  1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10, 1e-10,
  1e-10, 1e-10, 9.867e-11, 9.537e-11, 9e-11, 8.404e-11, 7.799e-11,
  7.205e-11, 6.616e-11, 6.036e-11, 5.475e-11, 5.007e-11, 4.638e-11,
  4.346e-11, 4.055e-11, 3.763e-11, 3.471e-11, 3.186e-11, 2.905e-11,
  2.631e-11, 2.358e-11, 2.415e-11, 2.949e-11, 3.952e-11, 5.155e-11,
  6.76e-11, 8.741e-11, 1.099e-10, 1.278e-10, 1.414e-10, 1.512e-10,
  1.607e-10, 1.699e-10, 1.774e-10, 1.832e-10, 1.871e-10, 1.907e-10,
  1.943e-10, 1.974e-10, 1.993e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10,
  2e-10, 2e-10, 2e-10, 2e-10, 2e-10, 2e-10
};

static int ig_co2 = -999;

double co2, *q[NG] = { NULL };

int ig, ip, iw, iz;

/* Find emitter index of CO2... */
if (ig_co2 == -999)
  ig_co2 = find_emitter(ctl, "CO2");

/* Identify variable... */
for (ig = 0; ig < ctl->ng; ig++) {
  q[ig] = NULL;
  if (strcasecmp(ctl->emitter[ig], "C2H2") == 0)
    q[ig] = c2h2;
  if (strcasecmp(ctl->emitter[ig], "C2H6") == 0)
    q[ig] = c2h6;
  if (strcasecmp(ctl->emitter[ig], "CCl4") == 0)
    q[ig] = ccl4;
  if (strcasecmp(ctl->emitter[ig], "CH4") == 0)
    q[ig] = ch4;
  if (strcasecmp(ctl->emitter[ig], "ClO") == 0)
    q[ig] = clo;
  if (strcasecmp(ctl->emitter[ig], "ClONO2") == 0)
    q[ig] = clono2;
  if (strcasecmp(ctl->emitter[ig], "CO") == 0)
    q[ig] = co;
  if (strcasecmp(ctl->emitter[ig], "COF2") == 0)
    q[ig] = cof2;
  if (strcasecmp(ctl->emitter[ig], "F11") == 0)
    q[ig] = f11;
  if (strcasecmp(ctl->emitter[ig], "F12") == 0)
    q[ig] = f12;
  if (strcasecmp(ctl->emitter[ig], "F14") == 0)
    q[ig] = f14;
  if (strcasecmp(ctl->emitter[ig], "F22") == 0)
    q[ig] = f22;
  if (strcasecmp(ctl->emitter[ig], "H2O") == 0)
    q[ig] = h2o;
  if (strcasecmp(ctl->emitter[ig], "H2O2") == 0)
    q[ig] = h2o2;
  if (strcasecmp(ctl->emitter[ig], "HCN") == 0)
    q[ig] = hcn;
  if (strcasecmp(ctl->emitter[ig], "HNO3") == 0)
    q[ig] = hno3;
  if (strcasecmp(ctl->emitter[ig], "HNO4") == 0)
    q[ig] = hno4;
  if (strcasecmp(ctl->emitter[ig], "HOCl") == 0)
    q[ig] = hocl;
  if (strcasecmp(ctl->emitter[ig], "N2O") == 0)
    q[ig] = n2o;
  if (strcasecmp(ctl->emitter[ig], "N2O5") == 0)
    q[ig] = n2o5;
  if (strcasecmp(ctl->emitter[ig], "NH3") == 0)
    q[ig] = nh3;
  if (strcasecmp(ctl->emitter[ig], "NO") == 0)
    q[ig] = no;
  if (strcasecmp(ctl->emitter[ig], "NO2") == 0)
    q[ig] = no2;
  if (strcasecmp(ctl->emitter[ig], "O3") == 0)
    q[ig] = o3;
  if (strcasecmp(ctl->emitter[ig], "OCS") == 0)
    q[ig] = ocs;
  if (strcasecmp(ctl->emitter[ig], "SF6") == 0)
    q[ig] = sf6;
  if (strcasecmp(ctl->emitter[ig], "SO2") == 0)
    q[ig] = so2;
}

/* Loop over atmospheric data points... */
for (ip = 0; ip < atm->np; ip++) {

  /* Get altitude index... */
  iz = locate(z, 121, atm->z[ip]);

  /* Interpolate pressure... */
  atm->p[ip] = EXP(z[iz], pre[iz], z[iz + 1], pre[iz + 1], atm->z[ip]);

  /* Interpolate temperature... */
  atm->t[ip] = LIN(z[iz], tem[iz], z[iz + 1], tem[iz + 1], atm->z[ip]);

  /* Interpolate trace gases... */
```

```
    for (ig = 0; ig < ctl->ng; ig++)
      if (q[ig] != NULL)
        atm->q[ig][ip] =
          LIN(z[iz], q[ig][iz], z[iz + 1], q[ig][iz + 1], atm->z[ip]);
      else
        atm->q[ig][ip] = 0;

    /* Set CO2... */
    if (ig_co2 >= 0) {
      co2 =
        371.789948e-6 + 2.026214e-6 * (atm->time[ip] - 63158400.) / 31557600.;
      atm->q[ig_co2][ip] = co2;
    }

    /* Set extinction to zero... */
    for (iw = 0; iw < ctl->nw; iw++)
      atm->k[iw][ip] = 0;
  }
}
```

Here is the call graph for this function:



5.15.2.6 double ctmco2 (double *nu*, double *p*, double *t*, double *u*)

Compute carbon dioxide continuum (optical depth).

Definition at line 874 of file jurassic.c.

```
                 {

  static double co2296[2001] = { 9.3388e-5, 9.7711e-5, 1.0224e-4, 1.0697e-4,
    1.1193e-4, 1.1712e-4, 1.2255e-4, 1.2824e-4, 1.3419e-4, 1.4043e-4,
    1.4695e-4, 1.5378e-4, 1.6094e-4, 1.6842e-4, 1.7626e-4, 1.8447e-4,
    1.9307e-4, 2.0207e-4, 2.1149e-4, 2.2136e-4, 2.3169e-4, 2.4251e-4,
    2.5384e-4, 2.657e-4, 2.7813e-4, 2.9114e-4, 3.0477e-4, 3.1904e-4,
    3.3399e-4, 3.4965e-4, 3.6604e-4, 3.8322e-4, 4.0121e-4, 4.2006e-4,
    4.398e-4, 4.6047e-4, 4.8214e-4, 5.0483e-4, 5.286e-4, 5.535e-4,
    5.7959e-4, 6.0693e-4, 6.3557e-4, 6.6558e-4, 6.9702e-4, 7.2996e-4,
    7.6449e-4, 8.0066e-4, 8.3856e-4, 8.7829e-4, 9.1991e-4, 9.6354e-4,
    .0010093, .0010572, .0011074, .00116, .0012152, .001273,
    .0013336, .0013972, .0014638, .0015336, .0016068, .0016835,
    .001764, .0018483, .0019367, .0020295, .0021267, .0022286,
    .0023355, .0024476, .0025652, .0026885, .0028178, .0029534,
    .0030956, .0032448, .0034012, .0035654, .0037375, .0039181,
    .0041076, .0043063, .0045148, .0047336, .0049632, .005204,
    .0054567, .0057219, .0060002, .0062923, .0065988, .0069204,
    .007258, .0076123, .0079842, .0083746, .0087844, .0092146,
    .0096663, .01014, .010638, .011161, .01171, .012286, .012891,
    .013527, .014194, .014895, .015631, .016404, .017217, .01807,
    .018966, .019908, .020897, .021936, .023028, .024176, .025382,
    .026649, .027981, .02938, .030851, .032397, .034023, .035732,
    .037528, .039416, .041402, .04349, .045685, .047994, .050422,
    .052975, .055661, .058486, .061458, .064584, .067873, .071334,
    .074975, .078807, .082839, .087082, .091549, .096249, .1012,
    .10641, .11189, .11767, .12375, .13015, .13689, .14399, .15147,
    .15935, .16765, .17639, .18561, .19531, .20554, .21632, .22769,
    .23967, .25229, .2656, .27964, .29443, .31004, .3265, .34386,
    .36218, .3815, .40188, .42339, .44609, .47004, .49533, .52202,
.5502, .57995, .61137, .64455, .6796, .71663, .75574, .79707,
.84075, .88691, .9357, .98728, 1.0418, 1.0995, 1.1605, 1.225,
1.2932, 1.3654, 1.4418, 1.5227, 1.6083, 1.6989, 1.7948, 1.8964,
2.004, 2.118, 2.2388, 2.3668, 2.5025, 2.6463, 2.7988, 2.9606,
3.1321, 3.314, 3.5071, 3.712, 3.9296, 4.1605, 4.4058, 4.6663,
4.9431, 5.2374, 5.5501, 5.8818, 6.2353, 6.6114, 7.0115, 7.4372,
7.8905, 8.3731, 8.8871, 9.4349, 10.019, 10.641, 11.305, 12.013,
12.769, 13.576, 14.437, 15.358, 16.342, 17.39, 18.513, 19.716,
21.003, 22.379, 23.854, 25.436, 27.126, 28.942, 30.89, 32.973,
35.219, 37.634, 40.224, 43.021, 46.037, 49.29, 52.803, 56.447,
60.418, 64.792, 69.526, 74.637, 80.182, 86.193, 92.713, 99.786,
107.47, 115.84, 124.94, 134.86, 145.69, 157.49, 170.3, 184.39,
199.83, 216.4, 234.55, 254.72, 276.82, 299.85, 326.16, 354.99,
386.51, 416.68, 449.89, 490.12, 534.35, 578.25, 632.26, 692.61,
756.43, 834.75, 924.11, 1016.9, 996.96, 1102.7, 1219.2, 1351.9,
1494.3, 1654.1, 1826.5, 2027.9, 2249., 2453.8, 2714.4, 2999.4,
3209.5, 3509., 3840.4, 3907.5, 4190.7, 4533.5, 4648.3, 5059.1,
5561.6, 6191.4, 6820.8, 7905.9, 9362.2, 2431.3, 2211.3, 2046.8,
2023.8, 1985.9, 1905.9, 1491.1, 1369.8, 1262.2, 1200.7, 887.74,
820.25, 885.23, 887.21, 816.73, 1126.9, 1216.2, 1272.4, 1579.5,
1634.2, 1656.3, 1657.9, 1789.5, 1670.8, 1509.5, 8474.6, 7489.2,
6793.6, 6117., 5574.1, 5141.2, 5084.6, 4745.1, 4413.2, 4102.8,
4024.7, 3715., 3398.6, 3100.8, 2900.4, 2629.2, 2374., 2144.7,
1955.8, 1760.8, 1591.2, 1435.2, 1296.2, 1174., 1065.1, 967.76,
999.48, 897.45, 809.23, 732.77, 670.26, 611.93, 560.11, 518.77,
476.84, 438.8, 408.48, 380.21, 349.24, 322.71, 296.65, 272.85,
251.96, 232.04, 213.88, 197.69, 182.41, 168.41, 155.79, 144.05,
133.31, 123.48, 114.5, 106.21, 98.591, 91.612, 85.156, 79.204,
73.719, 68.666, 63.975, 59.637, 56.35, 52.545, 49.042, 45.788,
42.78, 39.992, 37.441, 35.037, 32.8, 30.744, 28.801, 26.986,
25.297, 23.731, 22.258, 20.883, 19.603, 18.403, 17.295, 16.249,
15.271, 14.356, 13.501, 12.701, 11.954, 11.254, 10.6, 9.9864,
9.4118, 8.8745, 8.3714, 7.8997, 7.4578, 7.0446, 6.6573, 6.2949,
5.9577, 5.6395, 5.3419, 5.063, 4.8037, 4.5608, 4.3452, 4.1364,
3.9413, 3.7394, 3.562, 3.3932, 3.2325, 3.0789, 2.9318, 2.7898,
2.6537, 2.5225, 2.3958, 2.2305, 2.1215, 2.0245, 1.9427, 1.8795,
1.8336, 1.7604, 1.7016, 1.6419, 1.5282, 1.4611, 1.3443, 1.27,
1.1675, 1.0824, 1.0534, .99833, .95854, .92981, .90887, .89346,
.88113, .87068, .86102, .85096, .88262, .86151, .83565, .80518,
.77045, .73736, .74744, .74954, .75773, .82267, .83493, .89402,
.89725, .93426, .95564, .94045, .94174, .93404, .92035, .90456,
.88621, .86673, .78117, .7515, .72056, .68822, .65658, .62764,
.55984, .55598, .57407, .60963, .63763, .66198, .61132, .60972,
.52496, .50649, .41872, .3964, .32422, .27276, .24048, .23772,
.2286, .22711, .23999, .32038, .34371, .36621, .38561, .39953,
.40636, .44913, .42716, .3919, .35477, .33935, .3351, .39746,
.40993, .49398, .49956, .56157, .54742, .57295, .57386, .55417,
.50745, .471, .43446, .39102, .34993, .31269, .27888, .24912,
.22291, .19994, .17972, .16197, .14633, .13252, .12029, .10942,
.099745, .091118, .083404, .076494, .070292, .064716, .059697,
.055173, .051093, .047411, .044089, .041092, .038392, .035965,
.033789, .031846, .030122, .028607, .02729, .026169, .025209,
.024405, .023766, .023288, .022925, .022716, .022681, .022685,
.022768, .023133, .023325, .023486, .024004, .024126, .024083,
.023785, .024023, .023029, .021649, .021108, .019454, .017809,
.017292, .016635, .017037, .018068, .018977, .018756, .017847,
.016557, .016142, .014459, .012869, .012381, .010875, .0098701,
.009285, .0091698, .0091701, .0096145, .010553, .01106, .012613,
.014362, .015017, .016507, .017741, .01768, .017784, .0171,
.016357, .016172, .017257, .018978, .020935, .021741, .023567,
.025183, .025589, .026732, .027648, .028278, .028215, .02856,
.029015, .029062, .028851, .028497, .027825, .027801, .026523,
.02487, .022967, .022168, .020194, .018605, .017903, .018439,
.019697, .020311, .020855, .020057, .018608, .016738, .015963,
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    .20051, .18899, .17815, .16801, .15846, .14954, .14117, .13328,
    .12584
  };

  double xw, dw, ew, cw296, cw260, cw230, dt230, dt260, dt296, ctw, ctmpth;

  int iw, jw;

  /* Get CO2 continuum absorption... */
  xw = nu / 2 + 1;
  if (xw >= 1 && xw < 2001) {
    iw = (int) xw;
    jw = iw + 1;
    dw = xw - iw;
    ew = 1 - dw;
    cw296 = ew * co2296[iw - 1] + dw * co2296[jw - 1];
    cw260 = ew * co2260[iw - 1] + dw * co2260[jw - 1];
    cw230 = ew * co2230[iw - 1] + dw * co2230[jw - 1];
    dt230 = t - 230;
    dt260 = t - 260;
    dt296 = t - 296;
    ctw = dt260 * 5.050505e-4 * dt296 * cw230 - dt230 * 9.259259e-4
      * dt296 * cw260 + dt230 * 4.208754e-4 * dt260 * cw296;
    ctmpth = u / GSL_CONST_NUM_AVOGADRO / 1000 * p / P0 * ctw;
  } else
    ctmpth = 0;
  return ctmpth;
}
```

5.15.2.7 double ctmh2o (double *nu*, double *p*, double *t*, double *q*, double *u*)

Compute water vapor continuum (optical depth).

Definition at line 1738 of file jurassic.c.

```
            {

  static double h2o296[2001] = { .17, .1695, .172, .168, .1687, .1624, .1606,
    .1508, .1447, .1344, .1214, .1133, .1009, .09217, .08297, .06989,
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    6.008e-16, 5.742e-16, 5.724e-16, 5.991e-16, 6.625e-16, 7.775e-16,
    9.734e-16, 1.306e-15, 1.88e-15, 2.879e-15, 4.616e-15, 7.579e-15,
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    1.481e-12, 1.813e-12, 2.232e-12, 2.722e-12, 3.254e-12, 3.845e-12,
    4.458e-12, 5.048e-12, 5.511e-12, 5.898e-12, 6.204e-12, 6.293e-12,
    6.386e-12, 6.467e-12, 6.507e-12, 6.466e-12, 6.443e-12, 6.598e-12,
    6.873e-12, 7.3e-12, 7.816e-12, 8.368e-12, 8.643e-12, 8.466e-12,
    7.871e-12, 6.853e-12, 5.714e-12, 4.482e-12, 3.392e-12, 2.613e-12,
    2.008e-12, 1.562e-12, 1.228e-12, 9.888e-13, 7.646e-13, 5.769e-13,
    4.368e-13, 3.324e-13, 2.508e-13, 1.916e-13
  };

  static double xfcrev[15] =
    { 1.003, 1.009, 1.015, 1.023, 1.029, 1.033, 1.037,
    1.039, 1.04, 1.046, 1.036, 1.027, 1.01, 1.002, 1.
  };

  double a1, a2, a3, dw, ew, dx, xw, xx, vf2, vf6, cw260, cw296,
    sfac, fscal, cwfrn, ctmpth, ctwfrn, ctwslf;

  int iw, jw, ix;

  /* Get H2O continuum absorption... */
  xw = nu / 10 + 1;
  if (xw >= 1 && xw < 2001) {
    iw = (int) xw;
    jw = iw + 1;
    dw = xw - iw;
    ew = 1 - dw;
    cw296 = ew * h2o296[iw - 1] + dw * h2o296[jw - 1];
    cw260 = ew * h2o260[iw - 1] + dw * h2o260[jw - 1];
    cwfrn = ew * h2ofrn[iw - 1] + dw * h2ofrn[jw - 1];
    if (nu <= 820 || nu >= 960) {
      sfac = 1;
    } else {
      xx = (nu - 820) / 10;
      ix = (int) xx;
      dx = xx - ix;
      sfac = (1 - dx) * xfcrev[ix] + dx * xfcrev[ix + 1];
    }
    ctwslf = sfac * cw296 * pow(cw260 / cw296, (296 - t) / (296 - 260));
    vf2 = gsl_pow_2(nu - 370);
    vf6 = gsl_pow_3(vf2);
    fscal = 36100 / (vf2 + vf6 * 1e-8 + 36100) * -.25 + 1;
    ctwfrn = cwfrn * fscal;
    a1 = nu * u * tanh(.7193876 / t * nu);
    a2 = 296 / t;
    a3 = p / P0 * (q * ctwslf + (1 - q) * ctwfrn) * 1e-20;
    ctmpth = a1 * a2 * a3;
  } else
    ctmpth = 0;
  return ctmpth;
}
```
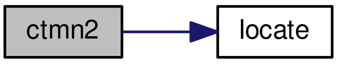

5.15.2.8 double ctmn2 (double *nu*, double *p*, double *t*)

Compute nitrogen continuum (absorption coefficient).

Definition at line 2792 of file jurassic.c.

```
           {

  static double ba[98] = { 0., 4.45e-8, 5.22e-8, 6.46e-8, 7.75e-8, 9.03e-8,
    1.06e-7, 1.21e-7, 1.37e-7, 1.57e-7, 1.75e-7, 2.01e-7, 2.3e-7,
    2.59e-7, 2.95e-7, 3.26e-7, 3.66e-7, 4.05e-7, 4.47e-7, 4.92e-7,
    5.34e-7, 5.84e-7, 6.24e-7, 6.67e-7, 7.14e-7, 7.26e-7, 7.54e-7,
    7.84e-7, 8.09e-7, 8.42e-7, 8.62e-7, 8.87e-7, 9.11e-7, 9.36e-7,
    9.76e-7, 1.03e-6, 1.11e-6, 1.23e-6, 1.39e-6, 1.61e-6, 1.76e-6,
    1.94e-6, 1.97e-6, 1.87e-6, 1.75e-6, 1.56e-6, 1.42e-6, 1.35e-6,
    1.32e-6, 1.29e-6, 1.29e-6, 1.29e-6, 1.3e-6, 1.32e-6, 1.33e-6,
    1.34e-6, 1.35e-6, 1.33e-6, 1.31e-6, 1.29e-6, 1.24e-6, 1.2e-6,
    1.16e-6, 1.1e-6, 1.04e-6, 9.96e-7, 9.38e-7, 8.63e-7, 7.98e-7,
    7.26e-7, 6.55e-7, 5.94e-7, 5.35e-7, 4.74e-7, 4.24e-7, 3.77e-7,
    3.33e-7, 2.96e-7, 2.63e-7, 2.34e-7, 2.08e-7, 1.85e-7, 1.67e-7,
    1.47e-7, 1.32e-7, 1.2e-7, 1.09e-7, 9.85e-8, 9.08e-8, 8.18e-8,
    7.56e-8, 6.85e-8, 6.14e-8, 5.83e-8, 5.77e-8, 5e-8, 4.32e-8, 0.
  };

  static double betaa[98] = { 802., 802., 761., 722., 679., 646., 609., 562.,
    511., 472., 436., 406., 377., 355., 338., 319., 299., 278., 255.,
    233., 208., 184., 149., 107., 66., 25., -13., -49., -82., -104.,
    -119., -130., -139., -144., -146., -146., -147., -148., -150.,
    -153., -160., -169., -181., -189., -195., -200., -205., -209.,
    -211., -210., -210., -209., -205., -199., -190., -180., -168.,
    -157., -143., -126., -108., -89., -63., -32., 1., 35., 65., 95.,
    121., 141., 152., 161., 164., 164., 161., 155., 148., 143., 137.,
    133., 131., 133., 139., 150., 165., 187., 213., 248., 284., 321.,
    372., 449., 514., 569., 609., 642., 673., 673.
  };

  static double nua[98] = { 2120., 2125., 2130., 2135., 2140., 2145., 2150.,
    2155., 2160., 2165., 2170., 2175., 2180., 2185., 2190., 2195.,
    2200., 2205., 2210., 2215., 2220., 2225., 2230., 2235., 2240.,
    2245., 2250., 2255., 2260., 2265., 2270., 2275., 2280., 2285.,
    2290., 2295., 2300., 2305., 2310., 2315., 2320., 2325., 2330.,
    2335., 2340., 2345., 2350., 2355., 2360., 2365., 2370., 2375.,
    2380., 2385., 2390., 2395., 2400., 2405., 2410., 2415., 2420.,
    2425., 2430., 2435., 2440., 2445., 2450., 2455., 2460., 2465.,
    2470., 2475., 2480., 2485., 2490., 2495., 2500., 2505., 2510.,
    2515., 2520., 2525., 2530., 2535., 2540., 2545., 2550., 2555.,
    2560., 2565., 2570., 2575., 2580., 2585., 2590., 2595., 2600., 2605.
  };

  double b, beta, q_n2 = 0.79, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[97])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 98, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t))
    * q_n2 * b * (q_n2 + (1 - q_n2) * (1.294 - 0.4545 * t / tr));
}
```

Here is the call graph for this function:



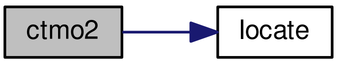
5.15.2.9 double ctmo2 (double *nu*, double *p*, double *t*)

Compute oxygen continuum (absorption coefficient).

Definition at line 2859 of file jurassic.c.

```
            {

  static double ba[90] = { 0., .061, .074, .084, .096, .12, .162, .208, .246,
    .285, .314, .38, .444, .5, .571, .673, .768, .853, .966, 1.097,
    1.214, 1.333, 1.466, 1.591, 1.693, 1.796, 1.922, 2.037, 2.154,
    2.264, 2.375, 2.508, 2.671, 2.847, 3.066, 3.417, 3.828, 4.204,
    4.453, 4.599, 4.528, 4.284, 3.955, 3.678, 3.477, 3.346, 3.29,
    3.251, 3.231, 3.226, 3.212, 3.192, 3.108, 3.033, 2.911, 2.798,
    2.646, 2.508, 2.322, 2.13, 1.928, 1.757, 1.588, 1.417, 1.253,
    1.109, .99, .888, .791, .678, .587, .524, .464, .403, .357, .32,
    .29, .267, .242, .215, .182, .16, .146, .128, .103, .087, .081,
    .071, .064, 0.
  };

  static double betaa[90] = { 467., 467., 400., 315., 379., 368., 475., 521.,
    531., 512., 442., 444., 430., 381., 335., 324., 296., 248., 215.,
    193., 158., 127., 101., 71., 31., -6., -26., -47., -63., -79.,
    -88., -88., -87., -90., -98., -99., -109., -134., -160., -167.,
    -164., -158., -153., -151., -156., -166., -168., -173., -170.,
    -161., -145., -126., -108., -84., -59., -29., 4., 41., 73., 97.,
    123., 159., 198., 220., 242., 256., 281., 311., 334., 319., 313.,
    321., 323., 310., 315., 320., 335., 361., 378., 373., 338., 319.,
    346., 322., 291., 290., 350., 371., 504., 504.
  };

  static double nua[90] = { 1360., 1365., 1370., 1375., 1380., 1385., 1390.,
    1395., 1400., 1405., 1410., 1415., 1420., 1425., 1430., 1435.,
    1440., 1445., 1450., 1455., 1460., 1465., 1470., 1475., 1480.,
    1485., 1490., 1495., 1500., 1505., 1510., 1515., 1520., 1525.,
    1530., 1535., 1540., 1545., 1550., 1555., 1560., 1565., 1570.,
    1575., 1580., 1585., 1590., 1595., 1600., 1605., 1610., 1615.,
    1620., 1625., 1630., 1635., 1640., 1645., 1650., 1655., 1660.,
    1665., 1670., 1675., 1680., 1685., 1690., 1695., 1700., 1705.,
    1710., 1715., 1720., 1725., 1730., 1735., 1740., 1745., 1750.,
    1755., 1760., 1765., 1770., 1775., 1780., 1785., 1790., 1795.,
    1800., 1805.
  };

  double b, beta, q_o2 = 0.21, t0 = 273, tr = 296;

  int idx;

  /* Check wavenumber range... */
  if (nu < nua[0] || nu > nua[89])
    return 0;

  /* Interpolate B and beta... */
  idx = locate(nua, 90, nu);
  b = LIN(nua[idx], ba[idx], nua[idx + 1], ba[idx + 1], nu);
  beta = LIN(nua[idx], betaa[idx], nua[idx + 1], betaa[idx + 1], nu);

  /* Compute absorption coefficient... */
  return 0.1 * gsl_pow_2(p / P0) * gsl_pow_2(t0 / t)
    * exp(beta * (1 / tr - 1 / t)) * q_o2 * b;
}
```

Here is the call graph for this function:



5.15.2.10 void copy_atm (ctl_t * *ctl*, atm_t * *atm_dest*, atm_t * *atm_src*, int *init*)

Copy and initialize atmospheric data.

Definition at line 2920 of file jurassic.c.

```
            {

  int ig, ip, iw;

  size_t s;

  /* Data size... */
  s = (size_t) atm_src->np * sizeof(double);

  /* Copy data... */
  atm_dest->np = atm_src->np;
  memcpy(atm_dest->time, atm_src->time, s);
  memcpy(atm_dest->z, atm_src->z, s);
  memcpy(atm_dest->lon, atm_src->lon, s);
  memcpy(atm_dest->lat, atm_src->lat, s);
  memcpy(atm_dest->p, atm_src->p, s);
  memcpy(atm_dest->t, atm_src->t, s);
  for (ig = 0; ig < ctl->ng; ig++)
    memcpy(atm_dest->q[ig], atm_src->q[ig], s);
  for (iw = 0; iw < ctl->nw; iw++)
    memcpy(atm_dest->k[iw], atm_src->k[iw], s);

  /* Initialize... */
  if (init)
    for (ip = 0; ip < atm_dest->np; ip++) {
      atm_dest->p[ip] = 0;
      atm_dest->t[ip] = 0;
      for (ig = 0; ig < ctl->ng; ig++)
        atm_dest->q[ig][ip] = 0;
      for (iw = 0; iw < ctl->nw; iw++)
        atm_dest->k[iw][ip] = 0;
    }
}
```

5.15.2.11 void copy_obs (ctl_t * *ctl*, obs_t * *obs_dest*, obs_t * *obs_src*, int *init*)

Copy and initialize observation data.

Definition at line 2960 of file jurassic.c.

```
            {

  int id, ir;

  size_t s;

  /* Data size... */
  s = (size_t) obs_src->nr * sizeof(double);

  /* Copy data... */
  obs_dest->nr = obs_src->nr;
  memcpy(obs_dest->time, obs_src->time, s);
  memcpy(obs_dest->obsz, obs_src->obsz, s);
  memcpy(obs_dest->obslon, obs_src->obslon, s);
  memcpy(obs_dest->obslat, obs_src->obslat, s);
  memcpy(obs_dest->vpz, obs_src->vpz, s);
  memcpy(obs_dest->vplon, obs_src->vplon, s);
  memcpy(obs_dest->vplat, obs_src->vplat, s);
  memcpy(obs_dest->tpz, obs_src->tpz, s);
  memcpy(obs_dest->tplon, obs_src->tplon, s);
  memcpy(obs_dest->tplat, obs_src->tplat, s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->rad[id], obs_src->rad[id], s);
  for (id = 0; id < ctl->nd; id++)
    memcpy(obs_dest->tau[id], obs_src->tau[id], s);

  /* Initialize... */
  if (init)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs_dest->nr; ir++)
        if (gsl_finite(obs_dest->rad[id][ir])) {
          obs_dest->rad[id][ir] = 0;
          obs_dest->tau[id][ir] = 0;
        }
}
```

5.15.2.12 int find_emitter (ctl_t * *ctl,* const char * *emitter*)

Find index of an emitter.

Definition at line 3002 of file jurassic.c.

```
                         {

  int ig;

  for (ig = 0; ig < ctl->ng; ig++)
    if (strcasecmp(ctl->emitter[ig], emitter) == 0)
      return ig;

  return -1;
}
```

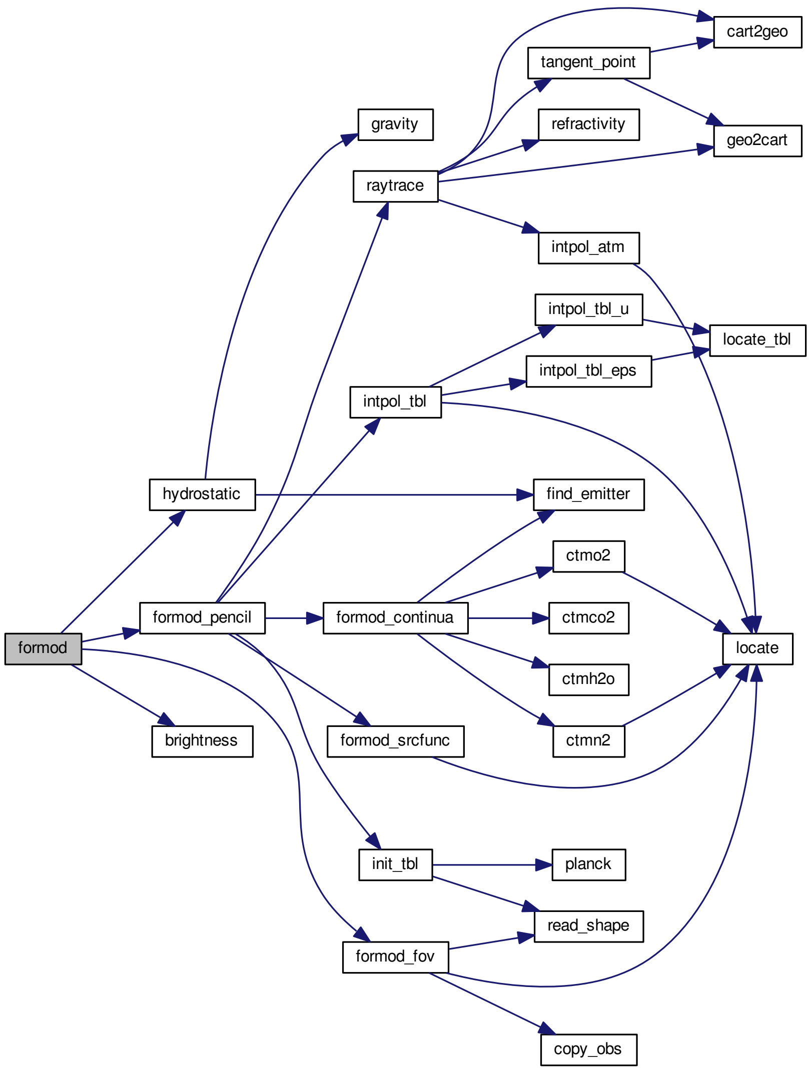
5.15.2.13 void formod (ctl_t * *ctl,* atm_t * *atm,* obs_t * *obs*)

Determine ray paths and compute radiative transfer.

Definition at line 3017 of file jurassic.c.

```
                 {

  int id, ir, *mask;

  /* Allocate... */
  ALLOC(mask, int,
        ND * NR);

  /* Save observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      mask[id * NR + ir] = !gsl_finite(obs->rad[id][ir]);

  /* Hydrostatic equilibrium... */
  hydrostatic(ctl, atm);

  /* Claculate pencil beams... */
  for (ir = 0; ir < obs->nr; ir++)
    formod_pencil(ctl, atm, obs, ir);

  /* Apply field-of-view convolution... */
  formod_fov(ctl, obs);

  /* Convert radiance to brightness temperature... */
  if (ctl->write_bbt)
    for (id = 0; id < ctl->nd; id++)
      for (ir = 0; ir < obs->nr; ir++)
        obs->rad[id][ir] = brightness(obs->rad[id][ir], ctl->nu[id]);

  /* Apply observation mask... */
  for (id = 0; id < ctl->nd; id++)
    for (ir = 0; ir < obs->nr; ir++)
      if (mask[id * NR + ir])
        obs->rad[id][ir] = GSL_NAN;

  /* Free... */
  free(mask);
}
```

Here is the call graph for this function:



5.15.2.14 void formod_continua (ctl_t * *ctl*, los_t * *los*, int *ip*, double * *beta*)

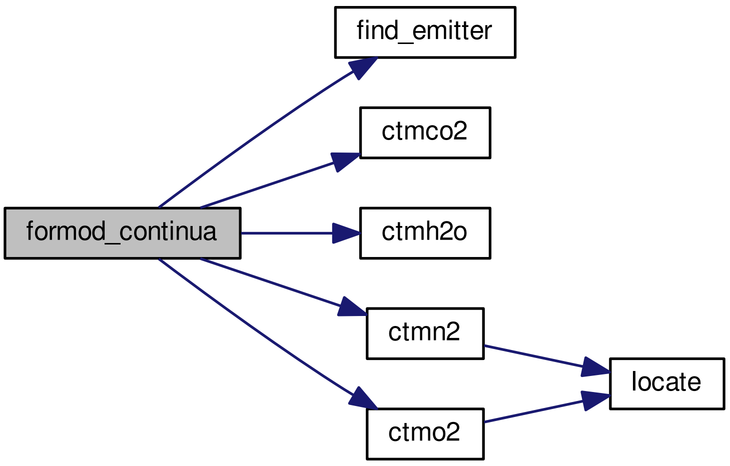
Compute absorption coefficient of continua.

Definition at line 3061 of file jurassic.c.

```
                 {

  static int ig_co2 = -999, ig_h2o = -999;

  int id;

  /* Extinction... */
  for (id = 0; id < ctl->nd; id++)
    beta[id] = los->k[ctl->window[id]][ip];

  /* CO2 continuum... */
  if (ctl->ctm_co2) {
    if (ig_co2 == -999)
```

```
      ig_co2 = find_emitter(ctl, "CO2");
    if (ig_co2 >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmco2(ctl->nu[id], los->p[ip], los->t[ip],
                           los->u[ig_co2][ip]) / los->ds[ip];
  }

  /* H2O continuum... */
  if (ctl->ctm_h2o) {
    if (ig_h2o == -999)
      ig_h2o = find_emitter(ctl, "H2O");
    if (ig_h2o >= 0)
      for (id = 0; id < ctl->nd; id++)
        beta[id] += ctmh2o(ctl->nu[id], los->p[ip], los->t[ip],
                           los->q[ig_h2o][ip],
                           los->u[ig_h2o][ip]) / los->ds[ip];
  }

  /* N2 continuum... */
  if (ctl->ctm_n2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmn2(ctl->nu[id], los->p[ip], los->t[ip]);

  /* O2 continuum... */
  if (ctl->ctm_o2)
    for (id = 0; id < ctl->nd; id++)
      beta[id] += ctmo2(ctl->nu[id], los->p[ip], los->t[ip]);
}
```

Here is the call graph for this function:



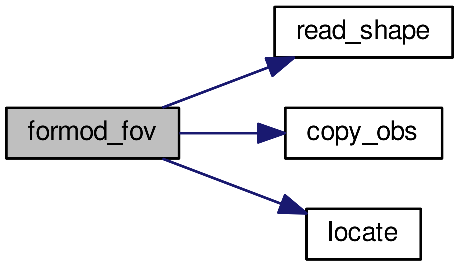
5.15.2.15 void formod_fov (**ctl_t** ∗ *ctl,* **obs_t** ∗ *obs*)

Apply field of view convolution.

Definition at line 3109 of file jurassic.c.

```
                {

  static double dz[NSHAPE], w[NSHAPE];

  static int init = 0, n;

  obs_t *obs2;

  double rad[ND][NR], tau[ND][NR], wsum, z[NR], zfov;

  int i, id, idx, ir, ir2, nz;

  /* Do not take into account FOV... */
  if (ctl->fov[0] == '-')
    return;

  /* Initialize FOV data... */
  if (!init) {
    init = 1;
    read_shape(ctl->fov, dz, w, &n);
  }

  /* Allocate... */
  ALLOC(obs2, obs_t, 1);

  /* Copy observation data... */
  copy_obs(ctl, obs2, obs, 0);

  /* Loop over ray paths... */
  for (ir = 0; ir < obs->nr; ir++) {

    /* Get radiance and transmittance profiles... */
    nz = 0;
    for (ir2 = GSL_MAX(ir - NFOV, 0); ir2 < GSL_MIN(ir + 1 + NFOV, obs->nr);
         ir2++)
      if (obs->time[ir2] == obs->time[ir]) {
        z[nz] = obs2->vpz[ir2];
        for (id = 0; id < ctl->nd; id++) {
          rad[id][nz] = obs2->rad[id][ir2];
          tau[id][nz] = obs2->tau[id][ir2];
        }
        nz++;
      }
    if (nz < 2)
      ERRMSG("Cannot apply FOV convolution!");

    /* Convolute profiles with FOV... */
    wsum = 0;
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] = 0;
      obs->tau[id][ir] = 0;
    }
    for (i = 0; i < n; i++) {
      zfov = obs->vpz[ir] + dz[i];
      idx = locate(z, nz, zfov);
      for (id = 0; id < ctl->nd; id++) {
        obs->rad[id][ir] += w[i]
          * LIN(z[idx], rad[id][idx], z[idx + 1], rad[id][idx + 1], zfov);
        obs->tau[id][ir] += w[i]
          * LIN(z[idx], tau[id][idx], z[idx + 1], tau[id][idx + 1], zfov);
      }
      wsum += w[i];
    }
    for (id = 0; id < ctl->nd; id++) {
      obs->rad[id][ir] /= wsum;
      obs->tau[id][ir] /= wsum;
    }
  }

  /* Free... */
  free(obs2);
}
```

Here is the call graph for this function:



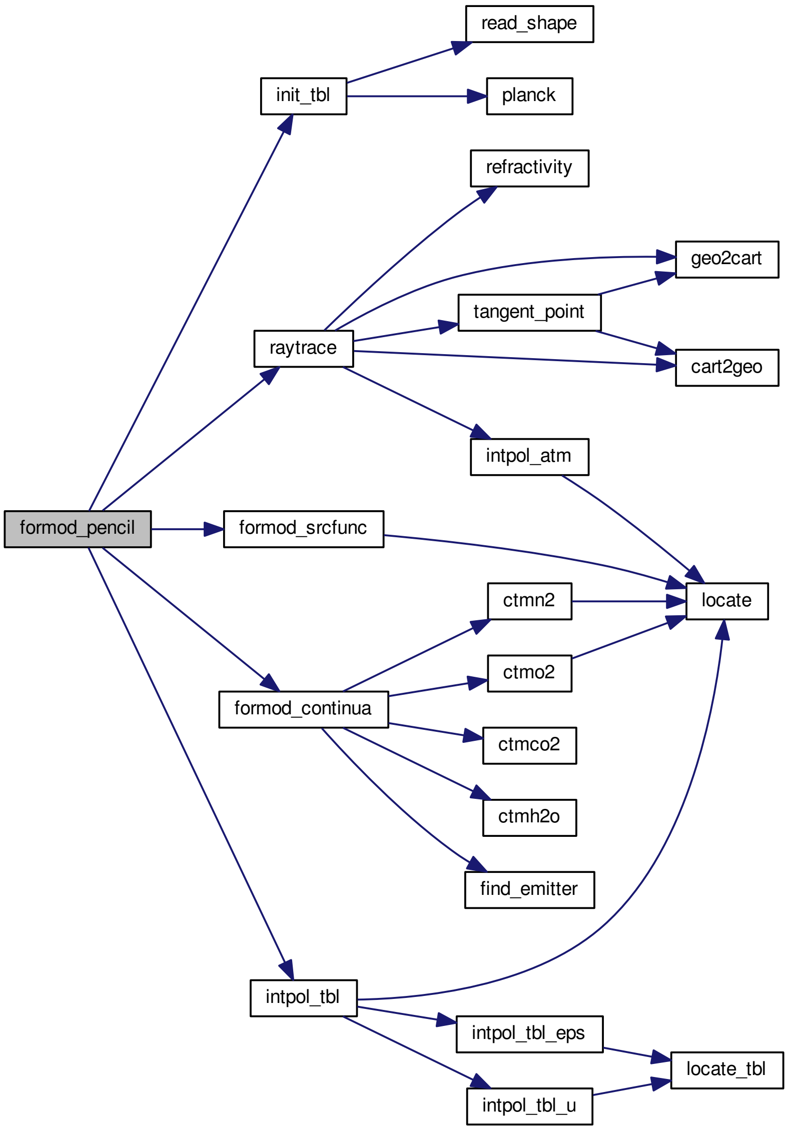
5.15.2.16 void formod_pencil (ctl_t * *ctl*, atm_t * *atm*, obs_t * *obs*, int *ir*)

Compute radiative transfer for a pencil beam.

Definition at line 3186 of file jurassic.c.

```
        {

  static tbl_t *tbl;

  static int init = 0;

  los_t *los;

  double beta_ctm[ND], eps, src_planck[ND], tau_path[NG][ND], tau_gas[ND];

  int id, ip;

  /* Initialize look-up tables... */
  if (!init) {
    init = 1;
    ALLOC(tbl, tbl_t, 1);
    init_tbl(ctl, tbl);
  }

  /* Allocate... */
  ALLOC(los, los_t, 1);

  /* Initialize... */
  for (id = 0; id < ctl->nd; id++) {
    obs->rad[id][ir] = 0;
    obs->tau[id][ir] = 1;
  }

  /* Raytracing... */
  raytrace(ctl, atm, obs, los, ir);

  /* Loop over LOS points... */
  for (ip = 0; ip < los->np; ip++) {

    /* Get trace gas transmittance... */
    intpol_tbl(ctl, tbl, los, ip, tau_path, tau_gas);

    /* Get continuum absorption... */
    formod_continua(ctl, los, ip, beta_ctm);

    /* Compute Planck function... */
    formod_srcfunc(ctl, tbl, los->t[ip], src_planck);

    /* Loop over channels... */
    for (id = 0; id < ctl->nd; id++)
      if (tau_gas[id] > 0) {

        /* Get segment emissivity... */
        eps = 1 - tau_gas[id] * exp(-beta_ctm[id] * los->ds[ip]);

        /* Compute radiance... */
        obs->rad[id][ir] += src_planck[id] * eps * obs->tau[id][ir];

        /* Compute path transmittance... */
        obs->tau[id][ir] *= (1 - eps);
      }
  }

  /* Add surface... */
  if (los->tsurf > 0) {
    formod_srcfunc(ctl, tbl, los->tsurf, src_planck);
    for (id = 0; id < ctl->nd; id++)
      obs->rad[id][ir] += src_planck[id] * obs->tau[id][ir];
  }

  /* Free... */
  free(los);
}
```

Here is the call graph for this function:



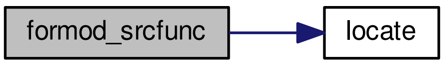
5.15.2.17 void formod_srcfunc (ctl_t * *ctl*, tbl_t * *tbl*, double *t*, double * *src*)

Compute Planck source function.

Definition at line 3261 of file jurassic.c.

```
                {

  int id, it;

  /* Determine index in temperature array... */
  it = locate(tbl->st, TBLNS, t);

  /* Interpolate Planck function value... */
  for (id = 0; id < ctl->nd; id++)
    src[id] = LIN(tbl->st[it], tbl->sr[id][it],
                  tbl->st[it + 1], tbl->sr[id][it + 1], t);
}
```

Here is the call graph for this function:



5.15.2.18 void geo2cart (double *z*, double *lon*, double *lat*, double * *x*)

Convert geolocation to Cartesian coordinates.

Definition at line 3280 of file jurassic.c.

```
              {

  double radius;

  radius = z + RE;
  x[0] = radius * cos(lat / 180 * M_PI) * cos(lon / 180 * M_PI);
  x[1] = radius * cos(lat / 180 * M_PI) * sin(lon / 180 * M_PI);
  x[2] = radius * sin(lat / 180 * M_PI);
}
```

5.15.2.19 double gravity (double *z*, double *lat*)

Determine gravity of Earth.

Definition at line 3296 of file jurassic.c.

```
               {

  /* Compute gravity according to 1967 Geodetic Reference System... */
  return 9.780318 * (1 + 0.0053024 * gsl_pow_2(sin(lat / 180 * M_PI))
                     - 0.0000058 * gsl_pow_2(sin(2 * lat / 180 * M_PI))) -
    3.086e-3 * z;
}
```

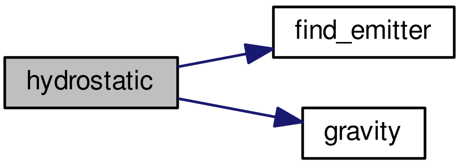
5.15.2.20 void hydrostatic (ctl_t * *ctl*, atm_t * *atm*)

Set hydrostatic equilibrium.

Definition at line 3308 of file jurassic.c.

```
                {

  static int ig_h2o = -999;

  double dzmin = 1e99, e = 0, mean, mmair = 28.96456e-3, mmh2o =
    18.0153e-3, z;

  int i, ip, ipref = 0, ipts = 20;

  /* Check reference height... */
  if (ctl->hydz < 0)
    return;

  /* Determine emitter index of H2O... */
  if (ig_h2o == -999)
    ig_h2o = find_emitter(ctl, "H2O");

  /* Find air parcel next to reference height... */
  for (ip = 0; ip < atm->np; ip++)
    if (fabs(atm->z[ip] - ctl->hydz) < dzmin) {
      dzmin = fabs(atm->z[ip] - ctl->hydz);
      ipref = ip;
    }

  /* Upper part of profile... */
  for (ip = ipref + 1; ip < atm->np; ip++) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip - 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip - 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip - 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip - 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip - 1]));
  }

  /* Lower part of profile... */
  for (ip = ipref - 1; ip >= 0; ip--) {
    mean = 0;
    for (i = 0; i < ipts; i++) {
      z = LIN(0.0, atm->z[ip + 1], ipts - 1.0, atm->z[ip], (double) i);
      if (ig_h2o >= 0)
        e = LIN(0.0, atm->q[ig_h2o][ip + 1],
                ipts - 1.0, atm->q[ig_h2o][ip], (double) i);
      mean += (e * mmh2o + (1 - e) * mmair)
        * gravity(z, atm->lat[ipref]) / GSL_CONST_MKSA_MOLAR_GAS
        / LIN(0.0, atm->t[ip + 1], ipts - 1.0, atm->t[ip], (double) i) / ipts;
    }

    /* Compute p(z,T)... */
    atm->p[ip] =
      exp(log(atm->p[ip + 1]) - mean * 1000 * (atm->z[ip] - atm->z[ip + 1]));
  }
}
```

Here is the call graph for this function:



5.15.2.21 void idx2name (ctl_t * *ctl*, int *idx*, char * *quantity*)

Determine name of state vector quantity for given index.

Definition at line 3373 of file jurassic.c.

```
                    {

  int ig, iw;

  if (idx == IDXP)
    sprintf(quantity, "PRESSURE");

  if (idx == IDXT)
    sprintf(quantity, "TEMPERATURE");

  for (ig = 0; ig < ctl->ng; ig++)
    if (idx == IDXQ(ig))
      sprintf(quantity, "%s", ctl->emitter[ig]);

  for (iw = 0; iw < ctl->nw; iw++)
    if (idx == IDXK(iw))
      sprintf(quantity, "EXTINCT_WINDOW%d", iw);
}
```

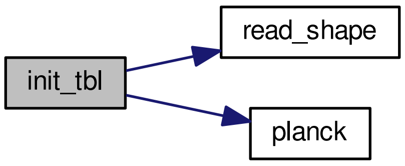
5.15.2.22 void init_tbl (ctl_t * *ctl*, tbl_t * *tbl*)

Initialize look-up tables.

Definition at line 3397 of file jurassic.c.

```
                 {

  FILE *in;

  char filename[LEN], line[LEN];

  double eps, eps_old, press, press_old, temp, temp_old, u, u_old,
    f[NSHAPE], fsum, nu[NSHAPE];

  int i, id, ig, ip, it, n;

  /* Loop over trace gases and channels... */
  for (ig = 0; ig < ctl->ng; ig++)
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(in,filename,line,eps,eps_old,press,
press_old,temp,temp_old,u,u_old,id,ip,it)
    for (id = 0; id < ctl->nd; id++) {

      /* Initialize... */
      tbl->np[ig][id] = -1;
      eps_old = -999;
      press_old = -999;
      temp_old = -999;
      u_old = -999;

      /* Try to open file... */
      sprintf(filename, "%s_%.4f_%s.tab",
              ctl->tblbase, ctl->nu[id], ctl->emitter[ig]);
      if (!(in = fopen(filename, "r"))) {
        printf("Missing emissivity table: %s\n", filename);
        continue;
      }
      printf("Read emissivity table: %s\n", filename);

      /* Read data... */
      while (fgets(line, LEN, in)) {

        /* Parse line... */
        if (sscanf(line, "%lg %lg %lg %lg", &press, &temp, &u, &eps) != 4)
          continue;

        /* Determine pressure index... */
        if (press != press_old) {
          press_old = press;
          if ((++tbl->np[ig][id]) >= TBLNP)
            ERRMSG("Too many pressure levels!");
          tbl->nt[ig][id][tbl->np[ig][id]] = -1;
        }

        /* Determine temperature index... */
        if (temp != temp_old) {
          temp_old = temp;
          if ((++tbl->nt[ig][id][tbl->np[ig][id]]) >= TBLNT)
            ERRMSG("Too many temperatures!");
          tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] = -1;
        }

        /* Determine column density index... */
        if ((eps > eps_old && u > u_old) || tbl->nu[ig][id][tbl->np[ig][id]]
            [tbl->nt[ig][id][tbl->np[ig][id]]] < 0) {
          eps_old = eps;
          u_old = u;
          if ((++tbl->nu[ig][id][tbl->np[ig][id]]
               [tbl->nt[ig][id][tbl->np[ig][id]]]) >= TBLNU) {
            tbl->nu[ig][id][tbl->np[ig][id]]
              [tbl->nt[ig][id][tbl->np[ig][id]]]--;
            continue;
          }
        }

        /* Store data... */
        tbl->p[ig][id][tbl->np[ig][id]] = press;
        tbl->t[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          = temp;
        tbl->u[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) u;
        tbl->eps[ig][id][tbl->np[ig][id]][tbl->nt[ig][id][tbl->np[ig][id]]]
          [tbl->nu[ig][id][tbl->np[ig][id]]
           [tbl->nt[ig][id][tbl->np[ig][id]]]] = (float) eps;
      }

      /* Increment counters... */
      tbl->np[ig][id]++;
      for (ip = 0; ip < tbl->np[ig][id]; ip++) {
        tbl->nt[ig][id][ip]++;
        for (it = 0; it < tbl->nt[ig][id][ip]; it++)
          tbl->nu[ig][id][ip][it]++;
      }

      /* Close file... */
      fclose(in);
    }

  /* Write info... */
  printf("Initialize source function table...\n");

  /* Loop over channels... */
#pragma omp parallel for default(none) shared(ctl,tbl,ig) private(filename,it,i,n,f,fsum,nu)
  for (id = 0; id < ctl->nd; id++) {

    /* Read filter function... */
    sprintf(filename, "%s_%.4f.filt", ctl->tblbase, ctl->nu[id]);
    read_shape(filename, nu, f, &n);

    /* Compute source function table... */
    for (it = 0; it < TBLNS; it++) {

      /* Set temperature... */
      tbl->st[it] = LIN(0.0, TMIN, TBLNS - 1.0, TMAX, (double) it);

      /* Integrate Planck function... */
      fsum = 0;
      tbl->sr[id][it] = 0;
      for (i = 0; i < n; i++) {
        fsum += f[i];
        tbl->sr[id][it] += f[i] * planck(tbl->st[it], nu[i]);
      }
      tbl->sr[id][it] /= fsum;
    }
  }
}
```

Here is the call graph for this function:



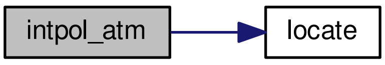
5.15.2.23 void intpol_atm (ctl_t * *ctl,* atm_t * *atm,* double *z,* double * *p,* double * *t,* double * *q,* double * *k*)

Interpolate atmospheric data.

Definition at line 3523 of file jurassic.c.

```
              {

  int ig, ip, iw;

  /* Get array index... */
  ip = locate(atm->z, atm->np, z);

  /* Interpolate... */
  *p = EXP(atm->z[ip], atm->p[ip], atm->z[ip + 1], atm->p[ip + 1], z);
  *t = LIN(atm->z[ip], atm->t[ip], atm->z[ip + 1], atm->t[ip + 1], z);
  for (ig = 0; ig < ctl->ng; ig++)
    q[ig] =
      LIN(atm->z[ip], atm->q[ig][ip], atm->z[ip + 1], atm->q[ig][ip + 1], z);
  for (iw = 0; iw < ctl->nw; iw++)
    k[iw] =
      LIN(atm->z[ip], atm->k[iw][ip], atm->z[ip + 1], atm->k[iw][ip + 1], z);
}
```

Here is the call graph for this function:



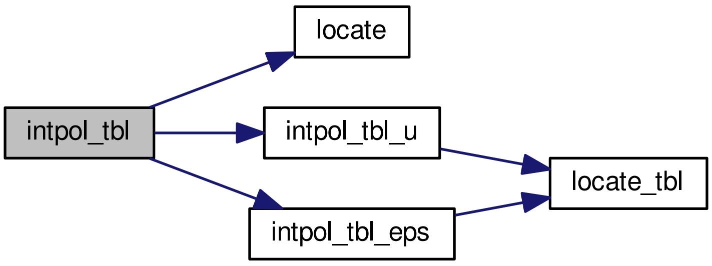
5.15.2.24 void intpol_tbl (ctl_t * *ctl*, tbl_t * *tbl*, los_t * *los*, int *ip*, double *tau_path[NG][ND]*, double *tau_seg[ND]*)

Get transmittance from look-up tables.

Definition at line 3550 of file jurassic.c.

```
                        {

  double eps, eps00, eps01, eps10, eps11, u;

  int id, ig, ipr, it0, it1;

  /* Initialize... */
  if (ip <= 0)
    for (ig = 0; ig < ctl->ng; ig++)
      for (id = 0; id < ctl->nd; id++)
        tau_path[ig][id] = 1;

  /* Loop over channels... */
  for (id = 0; id < ctl->nd; id++) {

    /* Initialize... */
    tau_seg[id] = 1;

    /* Loop over emitters.... */
    for (ig = 0; ig < ctl->ng; ig++) {

      /* Check size of table (pressure)... */
      if (tbl->np[ig][id] < 2)
        eps = 0;

      /* Check transmittance... */
      else if (tau_path[ig][id] < 1e-9)
        eps = 1;

      /* Interpolate... */
      else {

        /* Determine pressure and temperature indices... */
        ipr = locate(tbl->p[ig][id], tbl->np[ig][id], los->p[ip]);
        it0 = locate(tbl->t[ig][id][ipr], tbl->nt[ig][id][ipr], los->t[ip]);
        it1 =
          locate(tbl->t[ig][id][ipr + 1], tbl->nt[ig][id][ipr + 1],
                 los->t[ip]);

        /* Check size of table (temperature and column density)... */
        if (tbl->nt[ig][id][ipr] < 2 || tbl->nt[ig][id][ipr + 1] < 2
            || tbl->nu[ig][id][ipr][it0] < 2
            || tbl->nu[ig][id][ipr][it0 + 1] < 2
            || tbl->nu[ig][id][ipr + 1][it1] < 2
            || tbl->nu[ig][id][ipr + 1][it1 + 1] < 2)
          eps = 0;

        else {

          /* Get emissivities of extended path... */
          u = intpol_tbl_u(tbl, ig, id, ipr, it0, 1 - tau_path[ig][id]);
          eps00 = intpol_tbl_eps(tbl, ig, id, ipr, it0, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr, it0 + 1, 1 - tau_path[ig][id]);
          eps01 =
            intpol_tbl_eps(tbl, ig, id, ipr, it0 + 1, u + los->u[ig][ip]);

          u = intpol_tbl_u(tbl, ig, id, ipr + 1, it1, 1 - tau_path[ig][id]);
          eps10 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1, u + los->u[ig][ip]);

          u =
            intpol_tbl_u(tbl, ig, id, ipr + 1, it1 + 1, 1 - tau_path[ig][id]);
          eps11 =
            intpol_tbl_eps(tbl, ig, id, ipr + 1, it1 + 1, u + los->
u[ig][ip]);

          /* Interpolate with respect to temperature... */
          eps00 = LIN(tbl->t[ig][id][ipr][it0], eps00,
                      tbl->t[ig][id][ipr][it0 + 1], eps01, los->t[ip]);
          eps11 = LIN(tbl->t[ig][id][ipr + 1][it1], eps10,
                      tbl->t[ig][id][ipr + 1][it1 + 1], eps11, los->t[ip]);

          /* Interpolate with respect to pressure... */
          eps00 = LIN(tbl->p[ig][id][ipr], eps00,
                      tbl->p[ig][id][ipr + 1], eps11, los->p[ip]);

          /* Check emssivity range... */
          eps00 = GSL_MAX(GSL_MIN(eps00, 1), 0);

          /* Determine segment emissivity... */
          eps = 1 - (1 - eps00) / tau_path[ig][id];
        }
      }

      /* Get transmittance of extended path... */
      tau_path[ig][id] *= (1 - eps);

      /* Get segment transmittance... */
      tau_seg[id] *= (1 - eps);
    }
  }
}
```

Here is the call graph for this function:



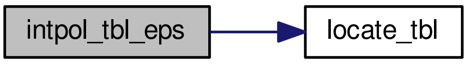
5.15.2.25 double intpol_tbl_eps (**tbl_t** ∗ *tbl,* int *ig,* int *id,* int *ip,* int *it,* double *u*)

Interpolate emissivity from look-up tables.

Definition at line 3651 of file jurassic.c.

```
              {

  int idx;

  /* Lower boundary... */
  if (u < tbl->u[ig][id][ip][it][0])
    return LIN(0, 0, tbl->u[ig][id][ip][it][0], tbl->eps[ig][id][ip][it][0],
               u);

  /* Upper boundary... */
  else if (u > tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1e30, 1, u);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->u[ig][id][ip][it], tbl->nu[ig][id][ip][it], u);

    /* Interpolate... */
    return
      LIN(tbl->u[ig][id][ip][it][idx], tbl->eps[ig][id][ip][it][idx],
          tbl->u[ig][id][ip][it][idx + 1], tbl->eps[ig][id][ip][it][idx + 1],
          u);
  }
}
```

Here is the call graph for this function:



5.15.2.26 double intpol_tbl_u (tbl_t * *tbl*, int *ig*, int *id*, int *ip*, int *it*, double *eps*)

Interpolate column density from look-up tables.

Definition at line 3688 of file jurassic.c.

```
                {

  int idx;

  /* Lower boundary... */
  if (eps < tbl->eps[ig][id][ip][it][0])
    return LIN(0, 0, tbl->eps[ig][id][ip][it][0], tbl->u[ig][id][ip][it][0],
               eps);

  /* Upper boundary... */
  else if (eps > tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1])
    return LIN(tbl->eps[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               tbl->u[ig][id][ip][it][tbl->nu[ig][id][ip][it] - 1],
               1, 1e30, eps);

  /* Interpolation... */
  else {

    /* Get index... */
    idx = locate_tbl(tbl->eps[ig][id][ip][it], tbl->nu[ig][id][ip][it], eps);

    /* Interpolate... */
    return
      LIN(tbl->eps[ig][id][ip][it][idx], tbl->u[ig][id][ip][it][idx],
          tbl->eps[ig][id][ip][it][idx + 1], tbl->u[ig][id][ip][it][idx + 1],
          eps);
  }
}
```

Here is the call graph for this function:

intpol_tbl_u
locate_tbl

5.15.2.27 void jsec2time (double *jsec*, int ∗ *year*, int ∗ *mon*, int ∗ *day*, int ∗ *hour*, int ∗ *min*, int ∗ *sec*, double ∗ *remain*)

Convert seconds to date.

Definition at line 3725 of file jurassic.c.

```
                    {

  struct tm t0, *t1;

  time_t jsec0;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  jsec0 = (time_t) jsec + timegm(&t0);
  t1 = gmtime(&jsec0);

  *year = t1->tm_year + 1900;
  *mon = t1->tm_mon + 1;
  *day = t1->tm_mday;
  *hour = t1->tm_hour;
  *min = t1->tm_min;
  *sec = t1->tm_sec;
  *remain = jsec - floor(jsec);
}
```

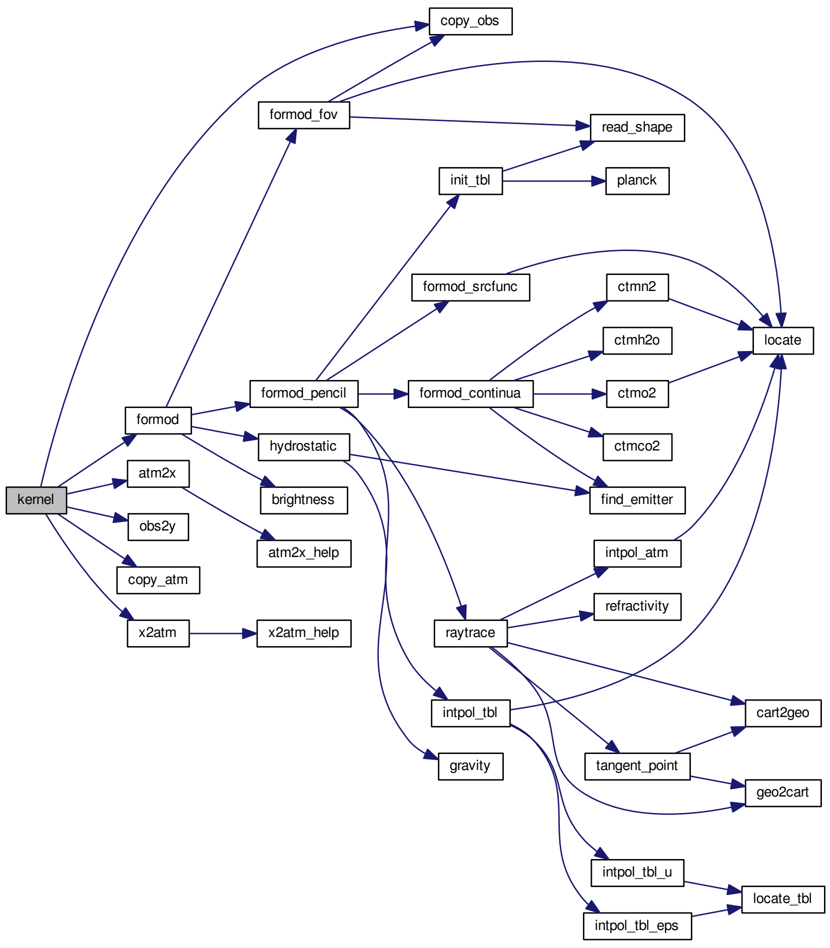
5.15.2.28 void kernel (ctl_t ∗ *ctl*, atm_t ∗ *atm*, obs_t ∗ *obs*, gsl_matrix ∗ *k*)

Compute Jacobians.

Definition at line 3760 of file jurassic.c.

```
                    {

  atm_t *atm1;
  obs_t *obs1;

  gsl_vector *x0, *x1, *yy0, *yy1;

  int *iqa, j;

  double h;

  size_t i, n, m;

  /* Get sizes... */
  m = k->size1;
  n = k->size2;

  /* Allocate... */
  x0 = gsl_vector_alloc(n);
  yy0 = gsl_vector_alloc(m);
  ALLOC(iqa, int,
        N);

  /* Compute radiance for undisturbed atmospheric data... */
  formod(ctl, atm, obs);

  /* Compose vectors... */
  atm2x(ctl, atm, x0, iqa, NULL);
  obs2y(ctl, obs, yy0, NULL, NULL);

  /* Initialize kernel matrix... */
  gsl_matrix_set_zero(k);

  /* Loop over state vector elements... */
#pragma omp parallel for default(none) shared(ctl,atm,obs,k,x0,yy0,n,m,iqa) private(i, j, h, x1, yy1, atm1,
 obs1)
  for (j = 0; j < (int) n; j++) {

    /* Allocate... */
    x1 = gsl_vector_alloc(n);
    yy1 = gsl_vector_alloc(m);
    ALLOC(atm1, atm_t, 1);
    ALLOC(obs1, obs_t, 1);

    /* Set perturbation size... */
    if (iqa[j] == IDXP)
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-7);
    else if (iqa[j] == IDXT)
      h = 1;
    else if (iqa[j] >= IDXQ(0) && iqa[j] < IDXQ(ctl->ng))
      h = GSL_MAX(fabs(0.01 * gsl_vector_get(x0, (size_t) j)), 1e-15);
    else if (iqa[j] >= IDXK(0) && iqa[j] < IDXK(ctl->nw))
      h = 1e-4;
    else
      ERRMSG("Cannot set perturbation size!");

    /* Disturb state vector element... */
    gsl_vector_memcpy(x1, x0);
    gsl_vector_set(x1, (size_t) j, gsl_vector_get(x1, (size_t) j) + h);
    copy_atm(ctl, atm1, atm, 0);
    copy_obs(ctl, obs1, obs, 0);
    x2atm(ctl, x1, atm1);

    /* Compute radiance for disturbed atmospheric data... */
    formod(ctl, atm1, obs1);

    /* Compose measurement vector for disturbed radiance data... */
    obs2y(ctl, obs1, yy1, NULL, NULL);

    /* Compute derivatives... */
    for (i = 0; i < m; i++)
      gsl_matrix_set(k, i, (size_t) j,
                     (gsl_vector_get(yy1, i) - gsl_vector_get(yy0, i)) / h);

    /* Free... */
    gsl_vector_free(x1);
    gsl_vector_free(yy1);
    free(atm1);
    free(obs1);
  }

  /* Free... */
  gsl_vector_free(x0);
  gsl_vector_free(yy0);
  free(iqa);
}
```

Here is the call graph for this function:



5.15.2.29 int locate (double ∗ *xx,* int *n,* double *x*)

Find array index.

Definition at line 3852 of file jurassic.c.

```
             {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  if (xx[i] < xx[i + 1])
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] > x)
        ihi = i;
      else
        ilo = i;
  } else
    while (ihi > ilo + 1) {
      i = (ihi + ilo) >> 1;
      if (xx[i] <= x)
        ihi = i;
      else
        ilo = i;
    }

  return ilo;
}
```

5.15.2.30 int locate_tbl (float * *xx*, int *n*, double *x*)

Find array index in float array.

Definition at line 3884 of file jurassic.c.

```
                {

  int i, ilo, ihi;

  ilo = 0;
  ihi = n - 1;
  i = (ihi + ilo) >> 1;

  while (ihi > ilo + 1) {
    i = (ihi + ilo) >> 1;
    if (xx[i] > x)
      ihi = i;
    else
      ilo = i;
  }

  return ilo;
}
```

5.15.2.31 size_t obs2y (ctl_t * *ctl*, obs_t * *obs*, gsl_vector * *y*, int * *ida*, int * *ira*)

Compose measurement vector.

Definition at line 3908 of file jurassic.c.

```
                {

  int id, ir;

  size_t m = 0;

  /* Determine measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        if (y != NULL)
          gsl_vector_set(y, m, obs->rad[id][ir]);
        if (ida != NULL)
          ida[m] = id;
        if (ira != NULL)
          ira[m] = ir;
        m++;
      }

  return m;
}
```

5.15.2.32 double planck (double *t*, double *nu*)

Compute Planck function.

Definition at line 3937 of file jurassic.c.

```
                 {

  return C1 * gsl_pow_3(nu) / gsl_expm1(C2 * nu / t);
}
```

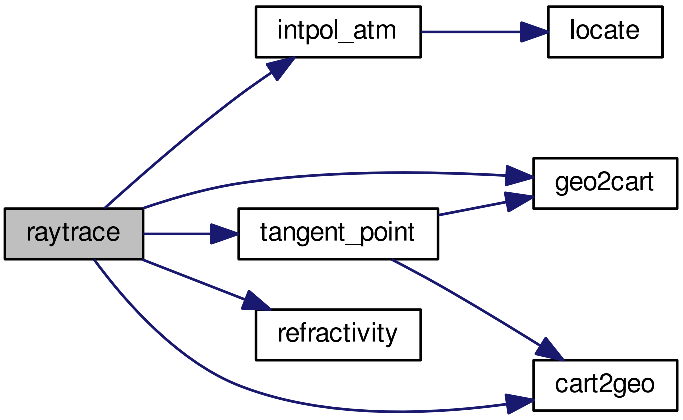
5.15.2.33 void raytrace (ctl_t ∗ *ctl*, atm_t ∗ *atm*, obs_t ∗ *obs*, los_t ∗ *los*, int *ir*)

Do ray-tracing to determine LOS.

Definition at line 3946 of file jurassic.c.

```
        {

double cosa, d, dmax, dmin = 0, ds, ex0[3], ex1[3], frac, h = 0.02, k[NW],
  lat, lon, n, naux, ng[3], norm, p, q[NG], t, x[3], xh[3],
  xobs[3], xvp[3], z = 1e99, zmax, zmin, zrefrac = 60;

int i, ig, ip, iw, stop = 0;

/* Initialize... */
los->np = 0;
los->tsurf = -999;
obs->tpz[ir] = obs->vpz[ir];
obs->tplon[ir] = obs->vplon[ir];
obs->tplat[ir] = obs->vplat[ir];

/* Get altitude range of atmospheric data... */
gsl_stats_minmax(&zmin, &zmax, atm->z, 1, (size_t) atm->np);

/* Check observer altitude... */
if (obs->obsz[ir] < zmin)
  ERRMSG("Observer below surface!");

/* Check view point altitude... */
if (obs->vpz[ir] > zmax)
  return;

/* Determine Cartesian coordinates for observer and view point... */
geo2cart(obs->obsz[ir], obs->obslon[ir], obs->obslat[ir], xobs);
geo2cart(obs->vpz[ir], obs->vplon[ir], obs->vplat[ir], xvp);

/* Determine initial tangent vector... */
for (i = 0; i < 3; i++)
  ex0[i] = xvp[i] - xobs[i];
norm = NORM(ex0);
for (i = 0; i < 3; i++)
  ex0[i] /= norm;

/* Observer within atmosphere... */
for (i = 0; i < 3; i++)
  x[i] = xobs[i];

/* Observer above atmosphere (search entry point)... */
if (obs->obsz[ir] > zmax) {
  dmax = norm;
  while (fabs(dmin - dmax) > 0.001) {
    d = (dmax + dmin) / 2;
    for (i = 0; i < 3; i++)
      x[i] = xobs[i] + d * ex0[i];
    cart2geo(x, &z, &lon, &lat);
    if (z <= zmax && z > zmax - 0.001)
      break;
    if (z < zmax - 0.0005)
      dmax = d;
    else
      dmin = d;
  }
}

/* Ray-tracing... */
while (1) {

  /* Set step length... */
  ds = ctl->rayds;
  if (ctl->raydz > 0) {
    norm = NORM(x);
    for (i = 0; i < 3; i++)
      xh[i] = x[i] / norm;
    cosa = fabs(DOTP(ex0, xh));
    if (cosa != 0)
      ds = GSL_MIN(ctl->rayds, ctl->raydz / cosa);
  }

  /* Determine geolocation... */
  cart2geo(x, &z, &lon, &lat);

  /* Check if LOS hits the ground or has left atmosphere... */
  if (z < zmin || z > zmax) {
    stop = (z < zmin ? 2 : 1);
    frac =
      ((z <
        zmin ? zmin : zmax) - los->z[los->np - 1]) / (z - los->z[los->np -
                                                                   1]);
    geo2cart(los->z[los->np - 1], los->lon[los->np - 1],
             los->lat[los->np - 1], xh);
    for (i = 0; i < 3; i++)
      x[i] = xh[i] + frac * (x[i] - xh[i]);
    cart2geo(x, &z, &lon, &lat);
    los->ds[los->np - 1] = ds * frac;
    ds = 0;
  }

  /* Interpolate atmospheric data... */
  intpol_atm(ctl, atm, z, &p, &t, q, k);

  /* Save data... */
  los->lon[los->np] = lon;
  los->lat[los->np] = lat;
  los->z[los->np] = z;
  los->p[los->np] = p;
  los->t[los->np] = t;
  for (ig = 0; ig < ctl->ng; ig++)
    los->q[ig][los->np] = q[ig];
  for (iw = 0; iw < ctl->nw; iw++)
    los->k[iw][los->np] = k[iw];
  los->ds[los->np] = ds;

  /* Increment and check number of LOS points... */
  if ((++los->np) > NLOS)
    ERRMSG("Too many LOS points!");

  /* Check stop flag... */
  if (stop) {
    los->tsurf = (stop == 2 ? t : -999);
    break;
  }

  /* Determine refractivity... */
  if (ctl->refrac && z <= zrefrac)
    n = 1 + refractivity(p, t);
  else
    n = 1;

  /* Construct new tangent vector (first term)... */
  for (i = 0; i < 3; i++)
    ex1[i] = ex0[i] * n;

  /* Compute gradient of refractivity... */
  if (ctl->refrac && z <= zrefrac) {
    for (i = 0; i < 3; i++)
      xh[i] = x[i] + 0.5 * ds * ex0[i];
    cart2geo(xh, &z, &lon, &lat);
    intpol_atm(ctl, atm, z, &p, &t, q, k);
    n = refractivity(p, t);
    for (i = 0; i < 3; i++) {
      xh[i] += h;
      cart2geo(xh, &z, &lon, &lat);
      intpol_atm(ctl, atm, z, &p, &t, q, k);
      naux = refractivity(p, t);
      ng[i] = (naux - n) / h;
      xh[i] -= h;
    }
  } else
    for (i = 0; i < 3; i++)
      ng[i] = 0;

  /* Construct new tangent vector (second term)... */
  for (i = 0; i < 3; i++)
    ex1[i] += ds * ng[i];

  /* Normalize new tangent vector... */
  norm = NORM(ex1);
  for (i = 0; i < 3; i++)
    ex1[i] /= norm;

  /* Determine next point of LOS... */
  for (i = 0; i < 3; i++)
    x[i] += 0.5 * ds * (ex0[i] + ex1[i]);

  /* Copy tangent vector... */
  for (i = 0; i < 3; i++)
    ex0[i] = ex1[i];
}

/* Get tangent point (to be done before changing segment lengths!)... */
tangent_point(los, &obs->tpz[ir], &obs->tplon[ir], &obs->
tplat[ir]);

/* Change segment lengths according to trapezoid rule... */
for (ip = los->np - 1; ip >= 1; ip--)
  los->ds[ip] = 0.5 * (los->ds[ip - 1] + los->ds[ip]);
los->ds[0] *= 0.5;

/* Compute column density... */
for (ip = 0; ip < los->np; ip++)
  for (ig = 0; ig < ctl->ng; ig++)
    los->u[ig][ip] = 10 * los->q[ig][ip] * los->p[ip]
      / (GSL_CONST_MKSA_BOLTZMANN * los->t[ip]) * los->ds[ip];
}
```

Here is the call graph for this function:



5.15.2.34 void read_atm (const char * *dirname,* const char * *filename,* ctl_t * *ctl,* atm_t * *atm*)

Read atmospheric data.

Definition at line 4131 of file jurassic.c.

```
                {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int ig, iw;

  /* Init... */
  atm->np = 0;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read atmospheric data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");
  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", atm->time[atm->np]);
    TOK(NULL, tok, "%lg", atm->z[atm->np]);
    TOK(NULL, tok, "%lg", atm->lon[atm->np]);
    TOK(NULL, tok, "%lg", atm->lat[atm->np]);
    TOK(NULL, tok, "%lg", atm->p[atm->np]);
    TOK(NULL, tok, "%lg", atm->t[atm->np]);
    for (ig = 0; ig < ctl->ng; ig++)
      TOK(NULL, tok, "%lg", atm->q[ig][atm->np]);
    for (iw = 0; iw < ctl->nw; iw++)
      TOK(NULL, tok, "%lg", atm->k[iw][atm->np]);

    /* Increment data point counter... */
    if ((++atm->np) > NP)
      ERRMSG("Too many data points!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (atm->np < 1)
    ERRMSG("Could not read any data!");
}
```

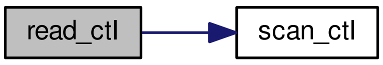
5.15.2.35 void read_ctl (int *argc,* char ∗ *argv[ ],* ctl_t ∗ *ctl*)

Read forward model control parameters.

Definition at line 4189 of file jurassic.c.

```
                {

  int id, ig, iw;

  /* Write info... */
  printf("\nJuelich Rapid Spectral Simulation Code (JURASSIC)\n"
         "(executable: %s | compiled: %s, %s)\n\n",
         argv[0], __DATE__, __TIME__);

  /* Emitters... */
  ctl->ng = (int) scan_ctl(argc, argv, "NG", -1, "0", NULL);
  if (ctl->ng < 0 || ctl->ng > NG)
    ERRMSG("Set 0 <= NG <= MAX!");
  for (ig = 0; ig < ctl->ng; ig++)
    scan_ctl(argc, argv, "EMITTER", ig, "", ctl->emitter[ig]);

  /* Radiance channels... */
  ctl->nd = (int) scan_ctl(argc, argv, "ND", -1, "0", NULL);
  if (ctl->nd < 0 || ctl->nd > ND)
    ERRMSG("Set 0 <= ND <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->nu[id] = scan_ctl(argc, argv, "NU", id, "", NULL);

  /* Spectral windows... */
  ctl->nw = (int) scan_ctl(argc, argv, "NW", -1, "1", NULL);
  if (ctl->nw < 0 || ctl->nw > NW)
    ERRMSG("Set 0 <= NW <= MAX!");
  for (id = 0; id < ctl->nd; id++)
    ctl->window[id] = (int) scan_ctl(argc, argv, "WINDOW", id, "0", NULL);

  /* Emissivity look-up tables... */
  scan_ctl(argc, argv, "TBLBASE", -1, "-", ctl->tblbase);

  /* Hydrostatic equilibrium... */
  ctl->hydz = scan_ctl(argc, argv, "HYDZ", -1, "-999", NULL);

  /* Continua... */
  ctl->ctm_co2 = (int) scan_ctl(argc, argv, "CTM_CO2", -1, "1", NULL);
  ctl->ctm_h2o = (int) scan_ctl(argc, argv, "CTM_H2O", -1, "1", NULL);
  ctl->ctm_n2 = (int) scan_ctl(argc, argv, "CTM_N2", -1, "1", NULL);
  ctl->ctm_o2 = (int) scan_ctl(argc, argv, "CTM_O2", -1, "1", NULL);

  /* Ray-tracing... */
  ctl->refrac = (int) scan_ctl(argc, argv, "REFRAC", -1, "1", NULL);
  ctl->rayds = scan_ctl(argc, argv, "RAYDS", -1, "10", NULL);
  ctl->raydz = scan_ctl(argc, argv, "RAYDZ", -1, "0.5", NULL);

  /* Field of view... */
  scan_ctl(argc, argv, "FOV", -1, "-", ctl->fov);

  /* Retrieval interface... */
  ctl->retp_zmin = scan_ctl(argc, argv, "RETP_ZMIN", -1, "-999", NULL);
  ctl->retp_zmax = scan_ctl(argc, argv, "RETP_ZMAX", -1, "-999", NULL);
  ctl->rett_zmin = scan_ctl(argc, argv, "RETT_ZMIN", -1, "-999", NULL);
  ctl->rett_zmax = scan_ctl(argc, argv, "RETT_ZMAX", -1, "-999", NULL);
  for (ig = 0; ig < ctl->ng; ig++) {
    ctl->retq_zmin[ig] = scan_ctl(argc, argv, "RETQ_ZMIN", ig, "-999", NULL);
    ctl->retq_zmax[ig] = scan_ctl(argc, argv, "RETQ_ZMAX", ig, "-999", NULL);
  }
  for (iw = 0; iw < ctl->nw; iw++) {
    ctl->retk_zmin[iw] = scan_ctl(argc, argv, "RETK_ZMIN", iw, "-999", NULL);
    ctl->retk_zmax[iw] = scan_ctl(argc, argv, "RETK_ZMAX", iw, "-999", NULL);
  }

  /* Output flags... */
  ctl->write_bbt = (int) scan_ctl(argc, argv, "WRITE_BBT", -1, "0", NULL);
  ctl->write_matrix =
    (int) scan_ctl(argc, argv, "WRITE_MATRIX", -1, "0", NULL);
}
```

Here is the call graph for this function:



5.15.2.36 void read_matrix (const char ∗ *dirname,* const char ∗ *filename,* gsl_matrix ∗ *matrix*)

Read matrix.

Definition at line 4264 of file jurassic.c.

```
                         {

  FILE *in;

  char dum[LEN], file[LEN], line[LEN];

  double value;

  int i, j;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read matrix: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  gsl_matrix_set_zero(matrix);
  while (fgets(line, LEN, in))
    if (sscanf(line, "%d %s %s %s %s %s %d %s %s %s %s %s %lg",
               &i, dum, dum, dum, dum, dum,
               &j, dum, dum, dum, dum, dum, &value) == 13)
      gsl_matrix_set(matrix, (size_t) i, (size_t) j, value);

  /* Close file... */
  fclose(in);
}
```

5.15.2.37 void read_obs (const char ∗ *dirname*, const char ∗ *filename*, ctl_t ∗ *ctl*, obs_t ∗ *obs*)

Read observation data.

Definition at line 4304 of file jurassic.c.

```
                {

  FILE *in;

  char file[LEN], line[LEN], *tok;

  int id;

  /* Init... */
  obs->nr = 0;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Read observation data: %s\n", file);

  /* Open file... */
  if (!(in = fopen(file, "r")))
    ERRMSG("Cannot open file!");

  /* Read line... */
  while (fgets(line, LEN, in)) {

    /* Read data... */
    TOK(line, tok, "%lg", obs->time[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obsz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->obslat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->vplat[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tpz[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplon[obs->nr]);
    TOK(NULL, tok, "%lg", obs->tplat[obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->rad[id][obs->nr]);
    for (id = 0; id < ctl->nd; id++)
      TOK(NULL, tok, "%lg", obs->tau[id][obs->nr]);

    /* Increment counter... */
    if ((++obs->nr) > NR)
      ERRMSG("Too many rays!");
  }

  /* Close file... */
  fclose(in);

  /* Check number of points... */
  if (obs->nr < 1)
    ERRMSG("Could not read any data!");
}
```

5.15.2.38 void read_shape (const char ∗ *filename*, double ∗ *x*, double ∗ *y*, int ∗ *n*)

Read shape function.

Definition at line 4366 of file jurassic.c.

```
         {

  FILE *in;

  char line[LEN];

  /* Write info... */
  printf("Read shape function: %s\n", filename);

  /* Open file... */
  if (!(in = fopen(filename, "r")))
    ERRMSG("Cannot open file!");

  /* Read data... */
  *n = 0;
  while (fgets(line, LEN, in))
    if (sscanf(line, "%lg %lg", &x[*n], &y[*n]) == 2)
      if ((++(*n)) > NSHAPE)
        ERRMSG("Too many data points!");

  /* Check number of points... */
  if (*n < 1)
    ERRMSG("Could not read any data!");

  /* Close file... */
  fclose(in);
}
```

5.15.2.39 double refractivity (double *p*, double *t*)

Compute refractivity (return value is n - 1).

Definition at line 4400 of file jurassic.c.

```
            {

  /* Refractivity of air at 4 to 15 micron... */
  return 7.753e-05 * p / t;
}
```

5.15.2.40 double scan_ctl (int *argc*, char ∗ *argv[ ]*, const char ∗ *varname*, int *arridx*, const char ∗ *defvalue*, char ∗ *value*)

Search control parameter file for variable entry.

Definition at line 4410 of file jurassic.c.

```
               {

  FILE *in = NULL;

  char dummy[LEN], fullname1[LEN], fullname2[LEN], line[LEN],
    msg[LEN], rvarname[LEN], rval[LEN];

  int contain = 0, i;

  /* Open file... */
  if (argv[1][0] != '-')
    if (!(in = fopen(argv[1], "r")))
      ERRMSG("Cannot open file!");

  /* Set full variable name... */
  if (arridx >= 0) {
    sprintf(fullname1, "%s[%d]", varname, arridx);
    sprintf(fullname2, "%s[*]", varname);
  } else {
    sprintf(fullname1, "%s", varname);
    sprintf(fullname2, "%s", varname);
  }

  /* Read data... */
  if (in != NULL)
    while (fgets(line, LEN, in))
      if (sscanf(line, "%s %s %s", rvarname, dummy, rval) == 3)
        if (strcasecmp(rvarname, fullname1) == 0 ||
            strcasecmp(rvarname, fullname2) == 0) {
          contain = 1;
          break;
        }
  for (i = 1; i < argc - 1; i++)
    if (strcasecmp(argv[i], fullname1) == 0 ||
        strcasecmp(argv[i], fullname2) == 0) {
      sprintf(rval, "%s", argv[i + 1]);
      contain = 1;
      break;
    }

  /* Close file... */
  if (in != NULL)
    fclose(in);

  /* Check for missing variables... */
  if (!contain) {
    if (strlen(defvalue) > 0)
      sprintf(rval, "%s", defvalue);
    else {
      sprintf(msg, "Missing variable %s!\n", fullname1);
      ERRMSG(msg);
    }
  }

  /* Write info... */
  printf("%s = %s\n", fullname1, rval);

  /* Return values... */
  if (value != NULL)
    sprintf(value, "%s", rval);
  return atof(rval);
}
```

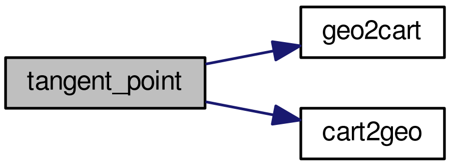
5.15.2.41 void tangent_point (los_t * *los,* double * *tpz,* double * *tplon,* double * *tplat*)

Find tangent point of a given LOS.

Definition at line 4481 of file jurassic.c.

```
                   {

  double a, b, c, dummy, v[3], v0[3], v2[3], x, x1, x2, yy0, yy1, yy2;

  size_t i, ip;

  /* Find minimum altitude... */
  ip = gsl_stats_min_index(los->z, 1, (size_t) los->np);

  /* Nadir or zenith... */
  if (ip <= 0 || ip >= (size_t) los->np - 1) {
    *tpz = los->z[los->np - 1];
    *tplon = los->lon[los->np - 1];
    *tplat = los->lat[los->np - 1];
  }

  /* Limb... */
  else {

    /* Determine interpolating polynomial y=a*x^2+b*x+c... */
    yy0 = los->z[ip - 1];
    yy1 = los->z[ip];
    yy2 = los->z[ip + 1];
    x1 = sqrt(gsl_pow_2(los->ds[ip]) - gsl_pow_2(yy1 - yy0));
    x2 = x1 + sqrt(gsl_pow_2(los->ds[ip + 1]) - gsl_pow_2(yy2 - yy1));
    a = 1 / (x1 - x2) * (-(yy0 - yy1) / x1 + (yy0 - yy2) / x2);
    b = -(yy0 - yy1) / x1 - a * x1;
    c = yy0;

    /* Get tangent point location... */
    x = -b / (2 * a);
    *tpz = a * x * x + b * x + c;
    geo2cart(los->z[ip - 1], los->lon[ip - 1], los->lat[ip - 1], v0);
    geo2cart(los->z[ip + 1], los->lon[ip + 1], los->lat[ip + 1], v2);
    for (i = 0; i < 3; i++)
      v[i] = LIN(0.0, v0[i], x2, v2[i], x);
    cart2geo(v, &dummy, tplon, tplat);
  }
}
```

Here is the call graph for this function:



5.15.2.42 void time2jsec (int *year*, int *mon*, int *day*, int *hour*, int *min*, int *sec*, double *remain*, double ∗ *jsec*)

Convert date to seconds.

Definition at line 4527 of file jurassic.c.

```
                 {

  struct tm t0, t1;

  t0.tm_year = 100;
  t0.tm_mon = 0;
  t0.tm_mday = 1;
  t0.tm_hour = 0;
  t0.tm_min = 0;
  t0.tm_sec = 0;

  t1.tm_year = year - 1900;
  t1.tm_mon = mon - 1;
  t1.tm_mday = day;
  t1.tm_hour = hour;
  t1.tm_min = min;
  t1.tm_sec = sec;

  *jsec = (double) timegm(&t1) - (double) timegm(&t0) + remain;
}
```

5.15.2.43 void timer (const char ∗ *name*, const char ∗ *file*, const char ∗ *func*, int *line*, int *mode*)

Measure wall-clock time.

Definition at line 4558 of file jurassic.c.

```
             {

  static double dt_w, w0[10];

  static int l0[10], nt;

  struct timeval tim;

  /* Start new timer... */
  if (mode == 1) {
    gettimeofday(&tim, NULL);
    w0[nt] = (double) tim.tv_sec + (double) tim.tv_usec / 1e6;
    l0[nt] = line;
    if ((++nt) >= 10)
      ERRMSG("Too many timers!");
  }

  /* Write elapsed time... */
  else {

    /* Check timer index... */
    if (nt - 1 < 0)
      ERRMSG("Coding error!");

    /* Get time differences... */
    gettimeofday(&tim, NULL);
    dt_w = (double) tim.tv_sec + (double) tim.tv_usec / 1e6 - w0[nt - 1];

    /* Write elapsed time... */
    printf("Timer '%s' (%s, %s, l%d-%d): %.3f sec\n",
           name, file, func, l0[nt - 1], line, dt_w);
  }

  /* Stop timer... */
  if (mode == 3)
    nt--;
}
```

5.15.2.44 void write_atm (const char * *dirname*, const char * *filename*, ctl_t * *ctl*, atm_t * *atm*)

Write atmospheric data.

Definition at line 4603 of file jurassic.c.

```
                 {

  FILE *out;

  char file[LEN];

  int ig, ip, iw, n = 6;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write atmospheric data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = altitude [km]\n"
          "# $3 = longitude [deg]\n"
          "# $4 = latitude [deg]\n"
          "# $5 = pressure [hPa]\n" "# $6 = temperature [K]\n");
  for (ig = 0; ig < ctl->ng; ig++)
    fprintf(out, "# $%d = %s volume mixing ratio\n", ++n, ctl->emitter[ig]);
  for (iw = 0; iw < ctl->nw; iw++)
    fprintf(out, "# $%d = window %d: extinction [1/km]\n", ++n, iw);

  /* Write data... */
  for (ip = 0; ip < atm->np; ip++) {
    if (ip == 0 || atm->lat[ip] != atm->lat[ip - 1]
        || atm->lon[ip] != atm->lon[ip - 1])
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g", atm->time[ip], atm->z[ip],
            atm->lon[ip], atm->lat[ip], atm->p[ip], atm->t[ip]);
    for (ig = 0; ig < ctl->ng; ig++)
      fprintf(out, " %g", atm->q[ig][ip]);
    for (iw = 0; iw < ctl->nw; iw++)
      fprintf(out, " %g", atm->k[iw][ip]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}
```

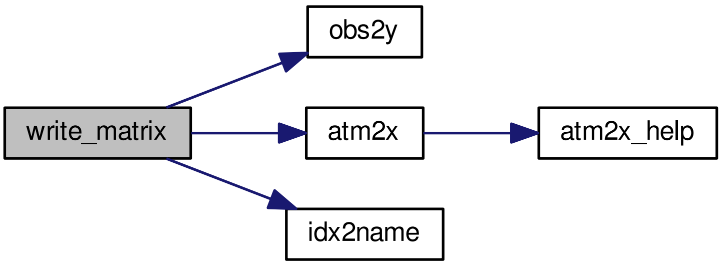
5.15.2.45 void write_matrix (const char ∗ *dirname*, const char ∗ *filename*, ctl_t ∗ *ctl*, gsl_matrix ∗ *matrix*, atm_t ∗ *atm*, obs_t ∗ *obs*, const char ∗ *rowspace*, const char ∗ *colspace*, const char ∗ *sort*)

Write matrix.

Definition at line 4660 of file jurassic.c.

```
                   {

  FILE *out;

  char file[LEN], quantity[LEN];

  int *cida, *ciqa, *cipa, *cira, *rida, *riqa, *ripa, *rira;

  size_t i, j, nc, nr;

  /* Check output flag... */
  if (!ctl->write_matrix)
    return;

  /* Allocate... */
  ALLOC(cida, int, M);
  ALLOC(ciqa, int,
        N);
  ALLOC(cipa, int,
        N);
  ALLOC(cira, int,
        M);
  ALLOC(rida, int,
        M);
  ALLOC(riqa, int,
        N);
  ALLOC(ripa, int,
        N);
  ALLOC(rira, int,
        M);

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write matrix: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header (row space)... */
  if (rowspace[0] == 'y') {

    fprintf(out,
            "# $1 = Row: index (measurement space)\n"
            "# $2 = Row: channel wavenumber [cm^-1]\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: view point altitude [km]\n"
            "# $5 = Row: view point longitude [deg]\n"
            "# $6 = Row: view point latitude [deg]\n");

    /* Get number of rows... */
    nr = obs2y(ctl, obs, NULL, rida, rira);

  } else {

    fprintf(out,
            "# $1 = Row: index (state space)\n"
            "# $2 = Row: name of quantity\n"
            "# $3 = Row: time (seconds since 2000-01-01T00:00Z)\n"
            "# $4 = Row: altitude [km]\n"
            "# $5 = Row: longitude [deg]\n" "# $6 = Row: latitude [deg]\n");

    /* Get number of rows... */
    nr = atm2x(ctl, atm, NULL, riqa, ripa);
  }

  /* Write header (column space)... */
  if (colspace[0] == 'y') {

    fprintf(out,
            "# $7 = Col: index (measurement space)\n"
            "# $8 = Col: channel wavenumber [cm^-1]\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: view point altitude [km]\n"
            "# $11 = Col: view point longitude [deg]\n"
            "# $12 = Col: view point latitude [deg]\n");

    /* Get number of columns... */
    nc = obs2y(ctl, obs, NULL, cida, cira);

  } else {

    fprintf(out,
            "# $7 = Col: index (state space)\n"
            "# $8 = Col: name of quantity\n"
            "# $9 = Col: time (seconds since 2000-01-01T00:00Z)\n"
            "# $10 = Col: altitude [km]\n"
            "# $11 = Col: longitude [deg]\n" "# $12 = Col: latitude [deg]\n");

    /* Get number of columns... */
    nc = atm2x(ctl, atm, NULL, ciqa, cipa);
  }

  /* Write header entry... */
  fprintf(out, "# $13 = Matrix element\n\n");

  /* Write matrix data... */
  i = j = 0;
  while (i < nr && j < nc) {

    /* Write info about the row... */
    if (rowspace[0] == 'y')
      fprintf(out, "%d %g %.2f %g %g %g",
              (int) i, ctl->nu[rida[i]],
              obs->time[rira[i]], obs->vpz[rira[i]],
              obs->vplon[rira[i]], obs->vplat[rira[i]]);
    else {
      idx2name(ctl, riqa[i], quantity);
      fprintf(out, "%d %s %.2f %g %g %g", (int) i, quantity,
              atm->time[ripa[i]], atm->z[ripa[i]],
              atm->lon[ripa[i]], atm->lat[ripa[i]]);
    }

    /* Write info about the column... */
    if (colspace[0] == 'y')
      fprintf(out, " %d %g %.2f %g %g %g",
              (int) j, ctl->nu[cida[j]],
              obs->time[cira[j]], obs->vpz[cira[j]],
              obs->vplon[cira[j]], obs->vplat[cira[j]]);
    else {
      idx2name(ctl, ciqa[j], quantity);
      fprintf(out, " %d %s %.2f %g %g %g", (int) j, quantity,
              atm->time[cipa[j]], atm->z[cipa[j]],
              atm->lon[cipa[j]], atm->lat[cipa[j]]);
    }

    /* Write matrix entry... */
    fprintf(out, " %g\n", gsl_matrix_get(matrix, i, j));

    /* Set matrix indices... */
    if (sort[0] == 'r') {
      j++;
      if (j >= nc) {
        j = 0;
        i++;
        fprintf(out, "\n");
      }
    } else {
      i++;
      if (i >= nr) {
        i = 0;
        j++;
        fprintf(out, "\n");
      }
    }
  }

  /* Close file... */
  fclose(out);

  /* Free... */
  free(cida);
  free(ciqa);
  free(cipa);
  free(cira);
  free(rida);
  free(riqa);
  free(ripa);
  free(rira);
}
```

Here is the call graph for this function:



5.15.2.46 void write_obs (const char ∗ *dirname,* const char ∗ *filename,* ctl_t ∗ *ctl,* obs_t ∗ *obs*)

Write observation data.

Definition at line 4837 of file jurassic.c.

```
                {

  FILE *out;

  char file[LEN];

  int id, ir, n = 10;

  /* Set filename... */
  if (dirname != NULL)
    sprintf(file, "%s/%s", dirname, filename);
  else
    sprintf(file, "%s", filename);

  /* Write info... */
  printf("Write observation data: %s\n", file);

  /* Create file... */
  if (!(out = fopen(file, "w")))
    ERRMSG("Cannot create file!");

  /* Write header... */
  fprintf(out,
          "# $1 = time (seconds since 2000-01-01T00:00Z)\n"
          "# $2 = observer altitude [km]\n"
          "# $3 = observer longitude [deg]\n"
          "# $4 = observer latitude [deg]\n"
          "# $5 = view point altitude [km]\n"
          "# $6 = view point longitude [deg]\n"
          "# $7 = view point latitude [deg]\n"
          "# $8 = tangent point altitude [km]\n"
          "# $9 = tangent point longitude [deg]\n"
          "# $10 = tangent point latitude [deg]\n");
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: radiance [W/(m^2 sr cm^-1)]\n",
            ++n, ctl->nu[id]);
  for (id = 0; id < ctl->nd; id++)
    fprintf(out, "# $%d = channel %g: transmittance\n", ++n, ctl->nu[id]);

  /* Write data... */
  for (ir = 0; ir < obs->nr; ir++) {
    if (ir == 0 || obs->time[ir] != obs->time[ir - 1])
```

```
      fprintf(out, "\n");
    fprintf(out, "%.2f %g %g %g %g %g %g %g %g %g", obs->time[ir],
            obs->obsz[ir], obs->obslon[ir], obs->obslat[ir],
            obs->vpz[ir], obs->vplon[ir], obs->vplat[ir],
            obs->tpz[ir], obs->tplon[ir], obs->tplat[ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->rad[id][ir]);
    for (id = 0; id < ctl->nd; id++)
      fprintf(out, " %g", obs->tau[id][ir]);
    fprintf(out, "\n");
  }

  /* Close file... */
  fclose(out);
}
```

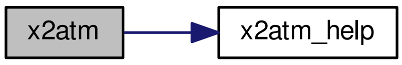
5.15.2.47 void x2atm (ctl_t ∗ *ctl,* gsl_vector ∗ *x,* atm_t ∗ *atm*)

Decompose parameter vector or state vector.

Definition at line 4901 of file jurassic.c.

```
                 {

  int ig, iw;

  size_t n = 0;

  /* Set pressure... */
  x2atm_help(atm, ctl->retp_zmin, ctl->retp_zmax, atm->
p, x, &n);

  /* Set temperature... */
  x2atm_help(atm, ctl->rett_zmin, ctl->rett_zmax, atm->
t, x, &n);

  /* Set volume mixing ratio... */
  for (ig = 0; ig < ctl->ng; ig++)
    x2atm_help(atm, ctl->retq_zmin[ig], ctl->retq_zmax[ig],
               atm->q[ig], x, &n);

  /* Set extinction... */
  for (iw = 0; iw < ctl->nw; iw++)
    x2atm_help(atm, ctl->retk_zmin[iw], ctl->retk_zmax[iw],
               atm->k[iw], x, &n);
}
```

Here is the call graph for this function:



5.15.2.48 void x2atm_help (atm_t ∗ *atm,* double *zmin,* double *zmax,* double ∗ *value,* gsl_vector ∗ *x,* size_t ∗ *n*)

Extract elements from state vector.

Definition at line 4929 of file jurassic.c.

```
                {

  int ip;

  /* Extract state vector elements... */
  for (ip = 0; ip < atm->np; ip++)
    if (atm->z[ip] >= zmin && atm->z[ip] <= zmax) {
      value[ip] = gsl_vector_get(x, *n);
      (*n)++;
    }
}
```

5.15.2.49 void y2obs (ctl_t * *ctl*, gsl_vector * *y*, obs_t * *obs*)

Decompose measurement vector.

Definition at line 4949 of file jurassic.c.

```
                {

  int id, ir;

  size_t m = 0;

  /* Decompose measurement vector... */
  for (ir = 0; ir < obs->nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      if (gsl_finite(obs->rad[id][ir])) {
        obs->rad[id][ir] = gsl_vector_get(y, m);
        m++;
      }
}
```

5.16 jurassic.h

```
/*
  This file is part of JURASSIC.

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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <sys/time.h>
#include <gsl/gsl_math.h>
#include <gsl/gsl_blas.h>
#include <gsl/gsl_const_mksa.h>
#include <gsl/gsl_const_num.h>
#include <gsl/gsl_linalg.h>
#include <gsl/gsl_statistics.h>

/* ------------------------------------------------------------
   Macros...
   ------------------------------------------------------------ */

#define ALLOC(ptr, type, n)                               \
  if((ptr=malloc((size_t)(n)*sizeof(type)))==NULL)      \
    ERRMSG("Out of memory!");

#define DIST(a, b) sqrt(DIST2(a, b))

#define DIST2(a, b)                                                     \
  ((a[0]-b[0])*(a[0]-b[0])+(a[1]-b[1])*(a[1]-b[1])+(a[2]-b[2])*(a[2]-b[2]))

#define DOTP(a, b) (a[0]*b[0]+a[1]*b[1]+a[2]*b[2])

#define ERRMSG(msg) {                                                   \
    printf("\nError (%s, %s, l%d): %s\n\n",                             \
           __FILE__, __func__, __LINE__, msg);                          \
    exit(EXIT_FAILURE);                                                 \
  }

#define EXP(x0, y0, x1, y1, x)                                  \
  (((y0)>0 && (y1)>0)                                           \
   ? ((y0)*exp(log((y1)/(y0))/((x1)-(x0))*((x)-(x0))))          \
    : LIN(x0, y0, x1, y1, x))

#define LIN(x0, y0, x1, y1, x)                  \
  ((y0)+((y1)-(y0))/((x1)-(x0))*((x)-(x0)))

#define NORM(a) sqrt(DOTP(a, a))

#define PRINT(format, var)                                          \
  printf("Print (%s, %s, l%d): %s= "format"\n",                     \
         __FILE__, __func__, __LINE__, #var, var);

#define TIMER(name, mode)                                \
  {timer(name, __FILE__, __func__, __LINE__, mode);}

#define TOK(line, tok, format, var) {                    \
    if(((tok)=strtok((line), " \t"))) {                  \
      if(sscanf(tok, format, &(var))!=1) continue;       \
    } else ERRMSG("Error while reading!");               \
  }

/* ------------------------------------------------------------
   Constants...
   ------------------------------------------------------------ */

#define C1 1.19104259e-8

#define C2 1.43877506

#define TMIN 100.

#define TMAX 400.

#define G0 9.80665

#define P0 1013.25

#define T0 273.15

#define RE 6367.421

#define ME 5.976e24

/* ------------------------------------------------------------
   Dimensions...
   ------------------------------------------------------------ */

#define ND 50

#define NG 20

#define NP 1000

#define NR 1000

#define NW 5

#define LEN 5000

#define M (NR*ND)

#define N (NQ*NP)

#define NQ (2+NG+NW)

#define NLOS 1000

#define NSHAPE 10000

#define NFOV 5

#define TBLNP 41

#define TBLNT 30

#define TBLNU 320

#define TBLNS 1200

/* ------------------------------------------------------------
   Quantity indices...
   ------------------------------------------------------------ */

#define IDXP 0

#define IDXT 1

#define IDXQ(ig) (2+ig)
```

```
#define IDXK(iw) (2+ctl->ng+iw)

/* ------------------------------------------------------------
   Structs...
   ------------------------------------------------------------ */

typedef struct {

  int np;

  double time[NP];

  double z[NP];

  double lon[NP];

  double lat[NP];

  double p[NP];

  double t[NP];

  double q[NG][NP];

  double k[NW][NP];

} atm_t;

typedef struct {

  int ng;

  char emitter[NG][LEN];

  int nd;

  int nw;

  double nu[ND];

  int window[ND];

  char tblbase[LEN];

  double hydz;

  int ctm_co2;

  int ctm_h2o;

  int ctm_n2;

  int ctm_o2;

  int refrac;

  double rayds;

  double raydz;

  char fov[LEN];

  double retp_zmin;

  double retp_zmax;

  double rett_zmin;

  double rett_zmax;

  double retq_zmin[NG];

  double retq_zmax[NG];

  double retk_zmin[NW];

  double retk_zmax[NW];

  int write_bbt;

  int write_matrix;

} ctl_t;

typedef struct {

  int np;

  double z[NLOS];

  double lon[NLOS];

  double lat[NLOS];

  double p[NLOS];

  double t[NLOS];

  double q[NG][NLOS];

  double k[NW][NLOS];

  double tsurf;

  double ds[NLOS];

  double u[NG][NLOS];

} los_t;

typedef struct {

  int nr;

  double time[NR];

  double obsz[NR];

  double obslon[NR];

  double obslat[NR];

  double vpz[NR];

  double vplon[NR];

  double vplat[NR];

  double tpz[NR];

  double tplon[NR];

  double tplat[NR];

  double tau[ND][NR];

  double rad[ND][NR];

} obs_t;

typedef struct {

  int np[NG][ND];

  int nt[NG][ND][TBLNP];

  int nu[NG][ND][TBLNP][TBLNT];

  double p[NG][ND][TBLNP];

  double t[NG][ND][TBLNP][TBLNT];

  float u[NG][ND][TBLNP][TBLNT][TBLNU];

  float eps[NG][ND][TBLNP][TBLNT][TBLNU];

  double st[TBLNS];

  double sr[ND][TBLNS];

} tbl_t;

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

size_t atm2x(
  ctl_t * ctl,
  atm_t * atm,
  gsl_vector * x,
  int *iqa,
  int *ipa);

```

```
void atm2x_help(
  atm_t * atm,
  double zmin,
  double zmax,
  double *value,
  int val_iqa,
  gsl_vector * x,
  int *iqa,
  int *ipa,
  size_t * n);

double brightness(
  double rad,
  double nu);

void cart2geo(
  double *x,
  double *z,
  double *lon,
  double *lat);

void climatology(
  ctl_t * ctl,
  atm_t * atm_mean);

double ctmco2(
  double nu,
  double p,
  double t,
  double u);

double ctmh2o(
  double nu,
  double p,
  double t,
  double q,
  double u);

double ctmn2(
  double nu,
  double p,
  double t);

double ctmo2(
  double nu,
  double p,
  double t);

void copy_atm(
  ctl_t * ctl,
  atm_t * atm_dest,
  atm_t * atm_src,
  int init);

void copy_obs(
  ctl_t * ctl,
  obs_t * obs_dest,
  obs_t * obs_src,
  int init);

int find_emitter(
  ctl_t * ctl,
  const char *emitter);

void formod(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs);

void formod_continua(
  ctl_t * ctl,
  los_t * los,
  int ip,
  double *beta);

void formod_fov(
  ctl_t * ctl,
  obs_t * obs);

void formod_pencil(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  int ir);

void formod_srcfunc(
  ctl_t * ctl,
  tbl_t * tbl,
  double t,
  double *src);

void geo2cart(
  double z,
  double lon,
  double lat,
  double *x);

double gravity(
  double z,
  double lat);

void hydrostatic(
  ctl_t * ctl,
  atm_t * atm);

void idx2name(
  ctl_t * ctl,
  int idx,
  char *quantity);

void init_tbl(
  ctl_t * ctl,
  tbl_t * tbl);

void intpol_atm(
  ctl_t * ctl,
  atm_t * atm,
  double z,
  double *p,
  double *t,
  double *q,
  double *k);

void intpol_tbl(
  ctl_t * ctl,
  tbl_t * tbl,
  los_t * los,
  int ip,
  double tau_path[NG][ND],
  double tau_seg[ND]);

double intpol_tbl_eps(
  tbl_t * tbl,
  int ig,
  int id,
  int ip,
  int it,
  double u);

double intpol_tbl_u(
  tbl_t * tbl,
  int ig,
  int id,
  int ip,
  int it,
  double eps);

void jsec2time(
  double jsec,
  int *year,
  int *mon,
  int *day,
  int *hour,
  int *min,
  int *sec,
  double *remain);

void kernel(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  gsl_matrix * k);

int locate(
  double *xx,
  int n,
  double x);

int locate_tbl(
  float *xx,
  int n,
  double x);

size_t obs2y(
  ctl_t * ctl,
  obs_t * obs,
  gsl_vector * y,
  int *ida,
  int *ira);

double planck(
  double t,
  double nu);

void raytrace(
  ctl_t * ctl,
  atm_t * atm,
  obs_t * obs,
  los_t * los,
  int ir);

void read_atm(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  atm_t * atm);

void read_ctl(
  int argc,
  char *argv[],
  ctl_t * ctl);

void read_matrix(
  const char *dirname,
  const char *filename,
  gsl_matrix * matrix);

void read_obs(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  obs_t * obs);

void read_shape(
  const char *filename,
  double *x,
  double *y,
  int *n);

double refractivity(
  double p,
  double t);

double scan_ctl(
  int argc,
  char *argv[],
  const char *varname,
  int arridx,
  const char *defvalue,
  char *value);

void tangent_point(
  los_t * los,
  double *tpz,
  double *tplon,
  double *tplat);

void time2jsec(
  int year,
  int mon,
  int day,
  int hour,
  int min,
  int sec,
  double remain,
  double *jsec);

void timer(
  const char *name,
  const char *file,
  const char *func,
  int line,
  int mode);

void write_atm(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  atm_t * atm);

void write_matrix(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  gsl_matrix * matrix,
  atm_t * atm,
  obs_t * obs,
  const char *rowspace,
  const char *colspace,
  const char *sort);

void write_obs(
  const char *dirname,
  const char *filename,
  ctl_t * ctl,
  obs_t * obs);

void x2atm(
  ctl_t * ctl,
  gsl_vector * x,
  atm_t * atm);

void x2atm_help(
  atm_t * atm,
  double zmin,
  double zmax,
  double *value,
  gsl_vector * x,
  size_t * n);

void y2obs(
  ctl_t * ctl,
  gsl_vector * y,
  obs_t * obs);
```

5.17 kernel.c File Reference

Calculate kernel functions.

Functions

- int main (int argc, char ∗argv[ ])

5.17.1 Detailed Description

Calculate kernel functions.

Definition in file kernel.c.

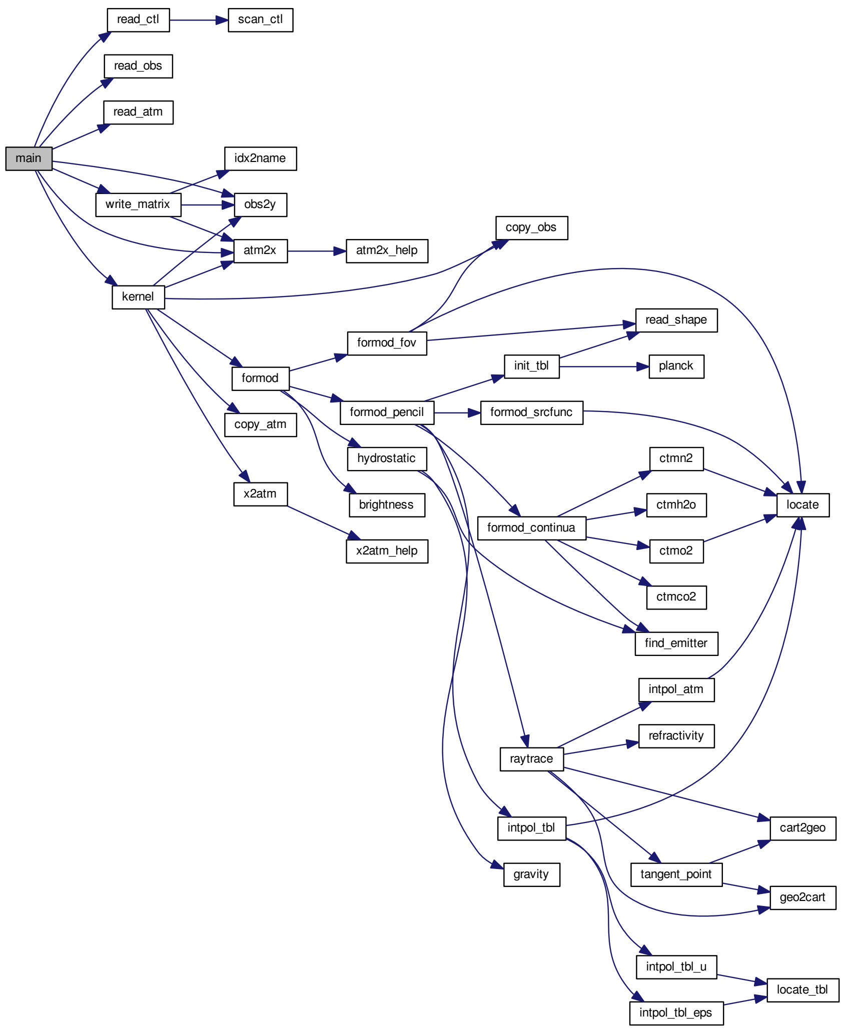
5.17.2 Function Documentation

5.17.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file kernel.c.

```
                  {

  static atm_t atm;
  static ctl_t ctl;
  static obs_t obs;

  gsl_matrix *k;

  size_t m, n;

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <obs> <atm> <kernel>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Set flags... */
  ctl.write_matrix = 1;

  /* Read observation geometry... */
  read_obs(NULL, argv[2], &ctl, &obs);

  /* Read atmospheric data... */
  read_atm(NULL, argv[3], &ctl, &atm);

  /* Get sizes... */
  n = atm2x(&ctl, &atm, NULL, NULL, NULL);
  m = obs2y(&ctl, &obs, NULL, NULL, NULL);

  /* Check sizes... */
  if (n <= 0)
    ERRMSG("No state vector elements!");
  if (m <= 0)
    ERRMSG("No measurement vector elements!");

  /* Allocate... */
  k = gsl_matrix_alloc(m, n);

  /* Compute kernel matrix... */
  kernel(&ctl, &atm, &obs, k);

  /* Write matrix to file... */
  write_matrix(NULL, argv[4], &ctl, k, &atm, &obs, "y", "x", "r");

  /* Free... */
  gsl_matrix_free(k);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.18 kernel.c

```
/*
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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static atm_t atm;
  static ctl_t ctl;
  static obs_t obs;

  gsl_matrix *k;

  size_t m, n;

  /* Check arguments... */
  if (argc < 5)
    ERRMSG("Give parameters: <ctl> <obs> <atm> <kernel>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Set flags... */
  ctl.write_matrix = 1;

  /* Read observation geometry... */
  read_obs(NULL, argv[2], &ctl, &obs);

  /* Read atmospheric data... */
  read_atm(NULL, argv[3], &ctl, &atm);

  /* Get sizes... */
  n = atm2x(&ctl, &atm, NULL, NULL, NULL);
  m = obs2y(&ctl, &obs, NULL, NULL, NULL);

  /* Check sizes... */
  if (n <= 0)
    ERRMSG("No state vector elements!");
  if (m <= 0)
    ERRMSG("No measurement vector elements!");

  /* Allocate... */
  k = gsl_matrix_alloc(m, n);

  /* Compute kernel matrix... */
  kernel(&ctl, &atm, &obs, k);

  /* Write matrix to file... */
  write_matrix(NULL, argv[4], &ctl, k, &atm, &obs, "y", "x", "r");

  /* Free... */
  gsl_matrix_free(k);

  return EXIT_SUCCESS;
}
```

5.19 limb.c File Reference

Create observation geometry for a limb sounder.

Functions

- int main (int argc, char ∗argv[ ])

5.19.1 Detailed Description

Create observation geometry for a limb sounder.

Definition in file limb.c.

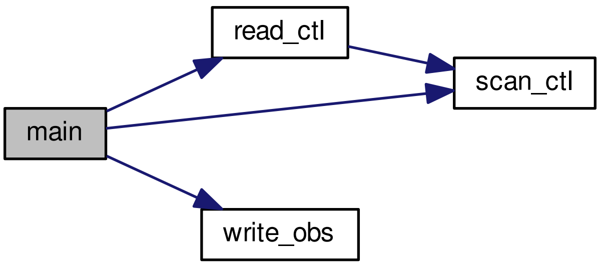
5.19.2 Function Documentation

5.19.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file limb.c.

```
                  {

  static ctl_t ctl;
  static obs_t obs;

  double dz, obsz, z, z0, z1;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <obs>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  obsz = scan_ctl(argc, argv, "OBSZ", -1, "780", NULL);
  z0 = scan_ctl(argc, argv, "Z0", -1, "6", NULL);
  z1 = scan_ctl(argc, argv, "Z1", -1, "70", NULL);
  dz = scan_ctl(argc, argv, "DZ", -1, "1.5", NULL);

  /* Create measurement geometry... */
  for (z = z0; z <= z1; z += dz) {
    obs.obsz[obs.nr] = obsz;
    obs.vpz[obs.nr] = z;
    obs.vplat[obs.nr] = 180 / M_PI * acos((RE + z) / (RE + obsz));
    if ((++obs.nr) >= NR)
      ERRMSG("Too many rays!");
  }

  /* Write observation data... */
  write_obs(NULL, argv[2], &ctl, &obs);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.20 limb.c

```
/*
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  it under the terms of the GNU General Public License as published by
  the Free Software Foundation, either version 3 of the License, or
  (at your option) any later version.

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  but WITHOUT ANY WARRANTY; without even the implied warranty of
  MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
  GNU General Public License for more details.

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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static ctl_t ctl;
  static obs_t obs;

  double dz, obsz, z, z0, z1;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <obs>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  obsz = scan_ctl(argc, argv, "OBSZ", -1, "780", NULL);
  z0 = scan_ctl(argc, argv, "Z0", -1, "6", NULL);
  z1 = scan_ctl(argc, argv, "Z1", -1, "70", NULL);
  dz = scan_ctl(argc, argv, "DZ", -1, "1.5", NULL);

  /* Create measurement geometry... */
  for (z = z0; z <= z1; z += dz) {
    obs.obsz[obs.nr] = obsz;
    obs.vpz[obs.nr] = z;
    obs.vplat[obs.nr] = 180 / M_PI * acos((RE + z) / (RE + obsz));
    if ((++obs.nr) >= NR)
      ERRMSG("Too many rays!");
  }

  /* Write observation data... */
  write_obs(NULL, argv[2], &ctl, &obs);

  return EXIT_SUCCESS;
}
```

5.21 nadir.c File Reference

Create observation geometry for a nadir sounder.

Functions

- int main (int argc, char *argv[ ])

5.21.1 Detailed Description

Create observation geometry for a nadir sounder.

Definition in file nadir.c.

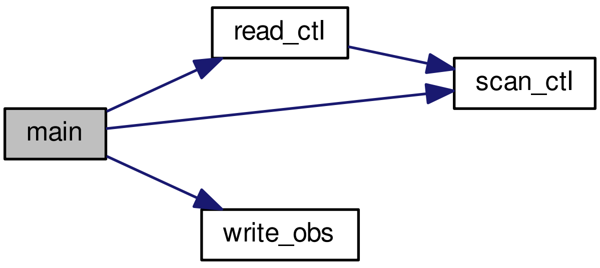
5.21.2 Function Documentation

5.21.2.1 int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 27 of file nadir.c.

```
                  {

  static ctl_t ctl;
  static obs_t obs;

  double dlat, lat, lat0, lat1, obsz;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <obs>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  obsz = scan_ctl(argc, argv, "OBSZ", -1, "700", NULL);
  lat0 = scan_ctl(argc, argv, "LAT0", -1, "-8.01", NULL);
  lat1 = scan_ctl(argc, argv, "LAT1", -1, "8.01", NULL);
  dlat = scan_ctl(argc, argv, "DLAT", -1, "0.18", NULL);

  /* Create measurement geometry... */
  for (lat = lat0; lat <= lat1; lat += dlat) {
    obs.obsz[obs.nr] = obsz;
    obs.vplat[obs.nr] = lat;
    if ((++obs.nr) >= NR)
      ERRMSG("Too many rays!");
  }

  /* Write observation data... */
  write_obs(NULL, argv[2], &ctl, &obs);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.22 nadir.c

```
/*
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  GNU General Public License for more details.

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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static ctl_t ctl;
  static obs_t obs;

  double dlat, lat, lat0, lat1, obsz;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <obs>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  obsz = scan_ctl(argc, argv, "OBSZ", -1, "700", NULL);
  lat0 = scan_ctl(argc, argv, "LAT0", -1, "-8.01", NULL);
  lat1 = scan_ctl(argc, argv, "LAT1", -1, "8.01", NULL);
  dlat = scan_ctl(argc, argv, "DLAT", -1, "0.18", NULL);

  /* Create measurement geometry... */
  for (lat = lat0; lat <= lat1; lat += dlat) {
    obs.obsz[obs.nr] = obsz;
    obs.vplat[obs.nr] = lat;
    if ((++obs.nr) >= NR)
      ERRMSG("Too many rays!");
  }

  /* Write observation data... */
  write_obs(NULL, argv[2], &ctl, &obs);

  return EXIT_SUCCESS;
}
```

5.23 planck.c File Reference

Convert brightness temperature to radiance.

Functions

- int main (int argc, char ∗argv[ ])

5.23.1 Detailed Description

Convert brightness temperature to radiance.

Definition in file planck.c.

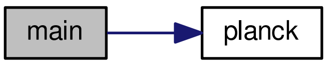
5.23.2 Function Documentation

5.23.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file planck.c.

```
                 {

  double nu, t;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <t> <nu>");

  /* Read arguments... */
  t = atof(argv[1]);
  nu = atof(argv[2]);

  /* Compute Planck function... */
  printf("%.10g\n", planck(t, nu));

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.24 planck.c

```
/*
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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  double nu, t;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <t> <nu>");

  /* Read arguments... */
  t = atof(argv[1]);
  nu = atof(argv[2]);

  /* Compute Planck function... */
  printf("%.10g\n", planck(t, nu));

  return EXIT_SUCCESS;
}
```

5.25 raytrace.c File Reference

Determine atmospheric ray paths.

Functions

- int main (int argc, char ∗argv[ ])

5.25.1 Detailed Description

Determine atmospheric ray paths.

Definition in file raytrace.c.

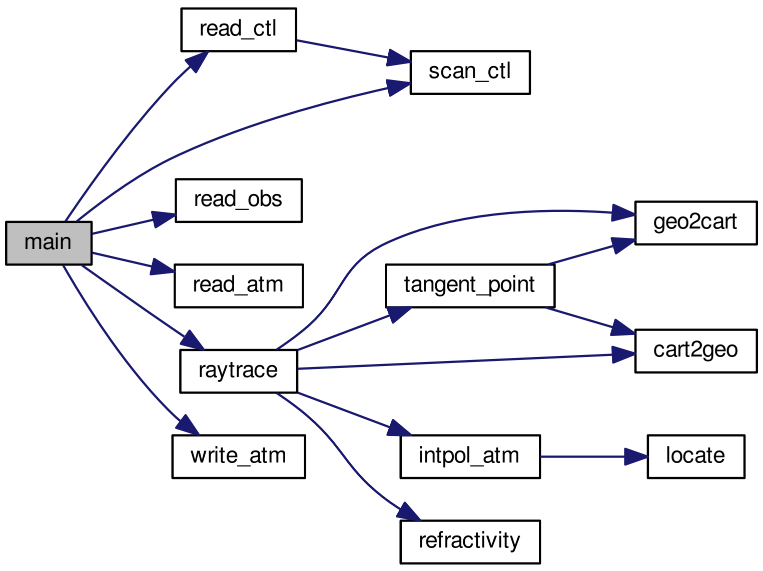
5.25.2 Function Documentation

5.25.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Definition at line 27 of file raytrace.c.

```
                  {

  static atm_t atm, atm2;
  static ctl_t ctl;
  static los_t los;
  static obs_t obs;

  char filename[LEN], losbase[LEN];

  int ig, ip, ir, iw;

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <obs> <atm>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Get basenames... */
  scan_ctl(argc, argv, "LOSBASE", -1, "los", losbase);

  /* Read observation geometry... */
  read_obs(NULL, argv[2], &ctl, &obs);

  /* Read atmospheric data... */
  read_atm(NULL, argv[3], &ctl, &atm);

  /* Loop over rays... */
  for (ir = 0; ir < obs.nr; ir++) {

    /* Raytracing... */
    raytrace(&ctl, &atm, &obs, &los, ir);

    /* Copy data... */
    atm2.np = los.np;
    for (ip = 0; ip < los.np; ip++) {
      atm2.time[ip] = obs.time[ir];
      atm2.z[ip] = los.z[ip];
      atm2.lon[ip] = los.lon[ip];
      atm2.lat[ip] = los.lat[ip];
      atm2.p[ip] = los.p[ip];
      atm2.t[ip] = los.t[ip];
      for (ig = 0; ig < ctl.ng; ig++)
        atm2.q[ig][ip] = los.q[ig][ip];
      for (iw = 0; iw < ctl.nw; iw++)
        atm2.k[iw][ip] = los.k[iw][ip];
    }

    /* Save data... */
    sprintf(filename, "los.%d", ir);
    write_atm(NULL, filename, &ctl, &atm2);
  }

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.26 raytrace.c

```
/*
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  GNU General Public License for more details.

  You should have received a copy of the GNU General Public License
  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

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*/

#include "jurassic.h"

int main(
  int argc,
  char *argv[]) {

  static atm_t atm, atm2;
  static ctl_t ctl;
  static los_t los;
  static obs_t obs;

  char filename[LEN], losbase[LEN];

  int ig, ip, ir, iw;

  /* Check arguments... */
  if (argc < 4)
    ERRMSG("Give parameters: <ctl> <obs> <atm>");

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);

  /* Get basenames... */
  scan_ctl(argc, argv, "LOSBASE", -1, "los", losbase);

  /* Read observation geometry... */
  read_obs(NULL, argv[2], &ctl, &obs);

  /* Read atmospheric data... */
  read_atm(NULL, argv[3], &ctl, &atm);

  /* Loop over rays... */
  for (ir = 0; ir < obs.nr; ir++) {

    /* Raytracing... */
    raytrace(&ctl, &atm, &obs, &los, ir);

    /* Copy data... */
    atm2.np = los.np;
    for (ip = 0; ip < los.np; ip++) {
      atm2.time[ip] = obs.time[ir];
      atm2.z[ip] = los.z[ip];
      atm2.lon[ip] = los.lon[ip];
      atm2.lat[ip] = los.lat[ip];
      atm2.p[ip] = los.p[ip];
      atm2.t[ip] = los.t[ip];
      for (ig = 0; ig < ctl.ng; ig++)
        atm2.q[ig][ip] = los.q[ig][ip];
      for (iw = 0; iw < ctl.nw; iw++)
        atm2.k[iw][ip] = los.k[iw][ip];
    }

    /* Save data... */
    sprintf(filename, "los.%d", ir);
    write_atm(NULL, filename, &ctl, &atm2);
  }

  return EXIT_SUCCESS;
}
```

5.27 retrieval.c File Reference

JURASSIC retrieval processor.

Data Structures

- struct ret_t

  Retrieval control parameters.

Functions

- void analyze_avk (ret_t ∗ret, ctl_t ∗ctl, atm_t ∗atm, int ∗iqa, int ∗ipa, gsl_matrix ∗avk)

  Compute information content and resolution.
- void analyze_avk_quantity (gsl_matrix ∗avk, int iq, int ∗ipa, size_t ∗n0, size_t ∗n1, double ∗cont, double ∗res)

  Analyze averaging kernels for individual retrieval target.
- double cost_function (gsl_vector ∗dx, gsl_vector ∗dy, gsl_matrix ∗s_a_inv, gsl_vector ∗sig_eps_inv)

  Compute cost function.
- void matrix_invert (gsl_matrix ∗a)

  Invert symmetric matrix.
- void matrix_product (gsl_matrix ∗a, gsl_vector ∗b, int transpose, gsl_matrix ∗c)

  Compute matrix product A^ TBA or ABA^ T for diagonal matrix B.
- void optimal_estimation (ret_t ∗ret, ctl_t ∗ctl, obs_t ∗obs_meas, obs_t ∗obs_i, atm_t ∗atm_apr, atm_t ∗atm_i)

  Carry out optimal estimation retrieval.
- void read_ret (int argc, char ∗argv[ ], ctl_t ∗ctl, ret_t ∗ret)

  Read retrieval control parameters.
- void set_cov_apr (ret_t ∗ret, ctl_t ∗ctl, atm_t ∗atm, int ∗iqa, int ∗ipa, gsl_matrix ∗s_a)

Set a priori covariance.

- void set_cov_meas (ret_t ∗ret, ctl_t ∗ctl, obs_t ∗obs, gsl_vector ∗sig_noise, gsl_vector ∗sig_formod, gsl_↩ vector ∗sig_eps_inv)

    Set measurement errors.

- void write_stddev (const char ∗quantity, ret_t ∗ret, ctl_t ∗ctl, atm_t ∗atm, gsl_matrix ∗s)

    Write retrieval error to file.

- int main (int argc, char ∗argv[ ])

5.27.1 Detailed Description

JURASSIC retrieval processor.

Definition in file retrieval.c.

5.27.2 Function Documentation

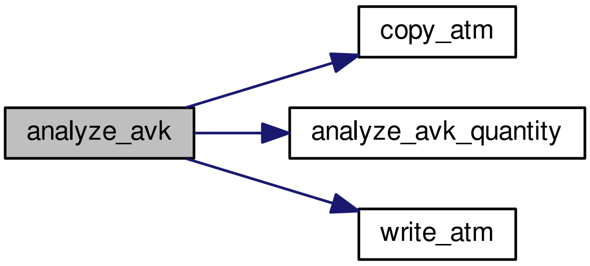
5.27.2.1 void analyze_avk (ret_t ∗ *ret,* ctl_t ∗ *ctl,* atm_t ∗ *atm,* int ∗ *iqa,* int ∗ *ipa,* gsl_matrix ∗ *avk*)

Compute information content and resolution.

Definition at line 236 of file retrieval.c.

```
                  {

  static atm_t atm_cont, atm_res;

  int ig, iq, iw;

  size_t i, n, n0[NQ], n1[NQ];

  /* Get sizes... */
  n = avk->size1;

  /* Find sub-matrices for different quantities... */
  for (iq = 0; iq < NQ; iq++) {
    n0[iq] = N;
    for (i = 0; i < n; i++) {
      if (iqa[i] == iq && n0[iq] == N)
        n0[iq] = i;
      if (iqa[i] == iq)
        n1[iq] = i - n0[iq] + 1;
    }
  }

  /* Initialize... */
  copy_atm(ctl, &atm_cont, atm, 1);
  copy_atm(ctl, &atm_res, atm, 1);

  /* Analyze quantities... */
  analyze_avk_quantity(avk, IDXP, ipa, n0, n1, atm_cont.p, atm_res.
p);
  analyze_avk_quantity(avk, IDXT, ipa, n0, n1, atm_cont.t, atm_res.
t);
  for (ig = 0; ig < ctl->ng; ig++)
    analyze_avk_quantity(avk, IDXQ(ig), ipa, n0, n1,
                         atm_cont.q[ig], atm_res.q[ig]);
  for (iw = 0; iw < ctl->nw; iw++)
    analyze_avk_quantity(avk, IDXK(iw), ipa, n0, n1,
                         atm_cont.k[iw], atm_res.k[iw]);

  /* Write results to disk... */
  write_atm(ret->dir, "atm_cont.tab", ctl, &atm_cont);
  write_atm(ret->dir, "atm_res.tab", ctl, &atm_res);
}
```

Here is the call graph for this function:



5.27.2.2 void analyze_avk_quantity (gsl_matrix ∗ *avk*, int *iq*, int ∗ *ipa*, size_t ∗ *n0*, size_t ∗ *n1*, double ∗ *cont*, double ∗ *res*)

Analyze averaging kernels for individual retrieval target.

Definition at line 285 of file retrieval.c.

```
                {

  size_t i, j;

  /* Loop over state vector elements... */
  if (n0[iq] < N)
    for (i = 0; i < n1[iq]; i++) {

      /* Get area of averagig kernel... */
      for (j = 0; j < n1[iq]; j++)
        cont[ipa[n0[iq] + i]] += gsl_matrix_get(avk, n0[iq] + i, n0[iq] + j);

      /* Get information density... */
      res[ipa[n0[iq] + i]] = 1 / gsl_matrix_get(avk, n0[iq] + i, n0[iq] + i);
    }
}
```

5.27.2.3 double cost_function (gsl_vector ∗ *dx*, gsl_vector ∗ *dy*, gsl_matrix ∗ *s_a_inv*, gsl_vector ∗ *sig_eps_inv*)

Compute cost function.

Definition at line 311 of file retrieval.c.

```
                             {

  gsl_vector *x_aux, *y_aux;

  double chisq_a, chisq_m = 0;

  size_t i, m, n;

  /* Get sizes... */
  m = dy->size;
  n = dx->size;

  /* Allocate... */
  x_aux = gsl_vector_alloc(n);
  y_aux = gsl_vector_alloc(m);

  /* Determine normalized cost function...
```

```
     (chi^2 = 1/m * [dy^T * S_eps^{-1} * dy + dx^T * S_a^{-1} * dx]) */
  for (i = 0; i < m; i++)
    chisq_m +=
      gsl_pow_2(gsl_vector_get(dy, i) * gsl_vector_get(sig_eps_inv, i));
  gsl_blas_dgemv(CblasNoTrans, 1.0, s_a_inv, dx, 0.0, x_aux);
  gsl_blas_ddot(dx, x_aux, &chisq_a);

  /* Free... */
  gsl_vector_free(x_aux);
  gsl_vector_free(y_aux);

  /* Return cost function value... */
  return (chisq_m + chisq_a) / (double) m;
}
```

5.27.2.4 void matrix_invert (gsl_matrix * *a*)

Invert symmetric matrix.

Definition at line 349 of file retrieval.c.

```
                  {

  size_t diag = 1, i, j, n;

  /* Get size... */
  n = a->size1;

  /* Check if matrix is diagonal... */
  for (i = 0; i < n && diag; i++)
    for (j = i + 1; j < n; j++)
      if (gsl_matrix_get(a, i, j) != 0) {
        diag = 0;
        break;
      }

  /* Quick inversion of diagonal matrix... */
  if (diag)
    for (i = 0; i < n; i++)
      gsl_matrix_set(a, i, i, 1 / gsl_matrix_get(a, i, i));

  /* Matrix inversion by means of Cholesky decomposition... */
  else {
    gsl_linalg_cholesky_decomp(a);
    gsl_linalg_cholesky_invert(a);
  }
}
```

5.27.2.5 void matrix_product (gsl_matrix * *a,* gsl_vector * *b,* int *transpose,* gsl_matrix * *c*)

Compute matrix product A^TBA or ABA^T for diagonal matrix B.

Definition at line 379 of file retrieval.c.

```
                  {

  gsl_matrix *aux;

  size_t i, j, m, n;

  /* Set sizes... */
  m = a->size1;
  n = a->size2;

  /* Allocate... */
  aux = gsl_matrix_alloc(m, n);

  /* Compute A^T B A... */
  if (transpose == 1) {

    /* Compute B^1/2 A... */
    for (i = 0; i < m; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(aux, i, j,
                        gsl_vector_get(b, i) * gsl_matrix_get(a, i, j));

    /* Compute A^T B A = (B^1/2 A)^T (B^1/2 A)... */
    gsl_blas_dgemm(CblasTrans, CblasNoTrans, 1.0, aux, aux, 0.0, c);
  }

  /* Compute A B A^T... */
  else if (transpose == 2) {

    /* Compute A B^1/2... */
    for (i = 0; i < m; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(aux, i, j,
                       gsl_matrix_get(a, i, j) * gsl_vector_get(b, j));

    /* Compute A B A^T = (A B^1/2) (A B^1/2)^T... */
    gsl_blas_dgemm(CblasNoTrans, CblasTrans, 1.0, aux, aux, 0.0, c);
  }

  /* Free... */
  gsl_matrix_free(aux);
}
```

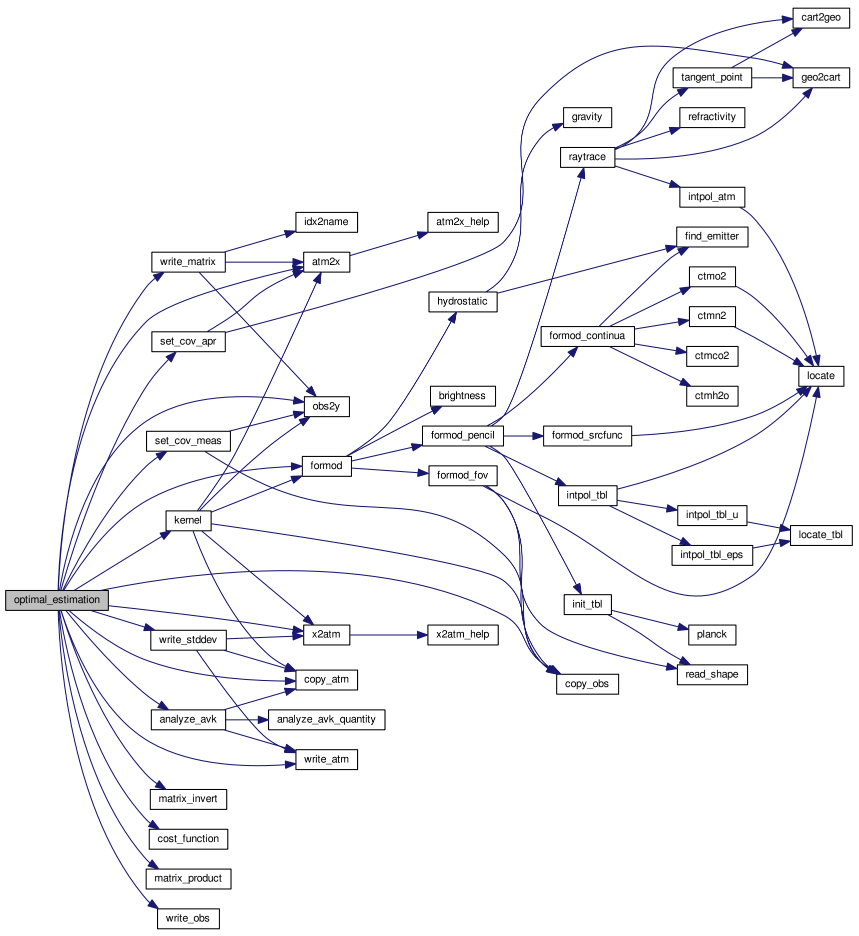
5.27.2.6 void optimal_estimation (ret_t * *ret*, ctl_t * *ctl*, obs_t * *obs_meas*, obs_t * *obs_i*, atm_t * *atm_apr*, atm_t * *atm_i*)

Carry out optimal estimation retrieval.

Definition at line 428 of file retrieval.c.

```
                  {

  static int ipa[N], iqa[N];

  gsl_matrix *a, *auxnm, *corr, *cov, *gain, *k_i, *s_a_inv;
  gsl_vector *b, *dx, *dy, *sig_eps_inv, *sig_formod, *sig_noise,
    *x_a, *x_i, *x_step, *y_aux, *y_i, *y_m;

  FILE *out;

  char filename[LEN];

  double chisq, chisq_old, disq = 0, lmpar = 0.001;

  int ig, ip, it = 0, it2, iw;

  size_t i, j, m, n;

  /* ------------------------------------------------------------
     Initialize...
     ------------------------------------------------------------ */

  /* Get sizes... */
  m = obs2y(ctl, obs_meas, NULL, NULL, NULL);
  n = atm2x(ctl, atm_apr, NULL, iqa, ipa);
  if (m <= 0 || n <= 0)
    ERRMSG("Check problem definition!");

  /* Write info... */
  printf("Problem size: m= %d / n= %d "
         "(alloc= %.4g MB / stat= %.4g MB)\n",
         (int) m, (int) n,
         (double) (3 * m * n + 4 * n * n + 8 * m +
                   8 * n) * sizeof(double) / 1024. / 1024.,
         (double) (5 * sizeof(atm_t) + 3 * sizeof(obs_t)
                   + 2 * N * sizeof(int)) / 1024. / 1024.);

  /* Allocate... */
  a = gsl_matrix_alloc(n, n);
  cov = gsl_matrix_alloc(n, n);
  k_i = gsl_matrix_alloc(m, n);
  s_a_inv = gsl_matrix_alloc(n, n);

  b = gsl_vector_alloc(n);
  dx = gsl_vector_alloc(n);
  dy = gsl_vector_alloc(m);
  sig_eps_inv = gsl_vector_alloc(m);
  sig_formod = gsl_vector_alloc(m);
  sig_noise = gsl_vector_alloc(m);
  x_a = gsl_vector_alloc(n);
  x_i = gsl_vector_alloc(n);
  x_step = gsl_vector_alloc(n);
  y_aux = gsl_vector_alloc(m);
  y_i = gsl_vector_alloc(m);
  y_m = gsl_vector_alloc(m);

  /* Set initial state... */
  copy_atm(ctl, atm_i, atm_apr, 0);
  copy_obs(ctl, obs_i, obs_meas, 0);
  formod(ctl, atm_i, obs_i);

  /* Set state vectors and observation vectors... */
  atm2x(ctl, atm_apr, x_a, NULL, NULL);
  atm2x(ctl, atm_i, x_i, NULL, NULL);
  obs2y(ctl, obs_meas, y_m, NULL, NULL);
  obs2y(ctl, obs_i, y_i, NULL, NULL);

  /* Set inverse a priori covariance S_a^-1... */
  set_cov_apr(ret, ctl, atm_apr, iqa, ipa, s_a_inv);
  write_matrix(ret->dir, "matrix_cov_apr.tab", ctl, s_a_inv,
               atm_i, obs_i, "x", "x", "r");
  matrix_invert(s_a_inv);

  /* Get measurement errors... */
  set_cov_meas(ret, ctl, obs_meas, sig_noise, sig_formod, sig_eps_inv);

  /* Create cost function file... */
  sprintf(filename, "%s/costs.tab", ret->dir);
  if (!(out = fopen(filename, "w")))
    ERRMSG("Cannot create cost function file!");

  /* Write header... */
  fprintf(out,
          "# $1 = iteration number\n"
          "# $2 = normalized cost function\n"
          "# $3 = number of measurements\n"
          "# $4 = number of state vector elements\n\n");

  /* Determine dx = x_i - x_a and dy = y - F(x_i) ... */
  gsl_vector_memcpy(dx, x_i);
  gsl_vector_sub(dx, x_a);
  gsl_vector_memcpy(dy, y_m);
  gsl_vector_sub(dy, y_i);

  /* Compute cost function... */
  chisq = cost_function(dx, dy, s_a_inv, sig_eps_inv);

  /* Write info... */
  printf("it= %d / chi^2/m= %g\n", it, chisq);

  /* Write to cost function file... */
  fprintf(out, "%d %g %d %d\n", it, chisq, (int) m, (int) n);

  /* Compute initial kernel... */
  kernel(ctl, atm_i, obs_i, k_i);

  /* ------------------------------------------------------------
     Levenberg-Marquardt minimization...
     ------------------------------------------------------------ */

  /* Outer loop... */
  for (it = 1; it <= ret->conv_itmax; it++) {

    /* Store current cost function value... */
    chisq_old = chisq;

    /* Compute kernel matrix K_i... */
    if (it > 1 && it % ret->kernel_recomp == 0)
      kernel(ctl, atm_i, obs_i, k_i);

    /* Compute K_i^T * S_eps^{-1} * K_i ... */
    if (it == 1 || it % ret->kernel_recomp == 0)
      matrix_product(k_i, sig_eps_inv, 1, cov);

    /* Determine b = K_i^T * S_eps^{-1} * dy - S_a^{-1} * dx ... */
    for (i = 0; i < m; i++)
      gsl_vector_set(y_aux, i, gsl_vector_get(dy, i)
                     * gsl_pow_2(gsl_vector_get(sig_eps_inv, i)));
    gsl_blas_dgemv(CblasTrans, 1.0, k_i, y_aux, 0.0, b);
    gsl_blas_dgemv(CblasNoTrans, -1.0, s_a_inv, dx, 1.0, b);

    /* Inner loop... */
    for (it2 = 0; it2 < 20; it2++) {

      /* Compute A = (1 + lmpar) * S_a^{-1} + K_i^T * S_eps^{-1} * K_i ... */
      gsl_matrix_memcpy(a, s_a_inv);
      gsl_matrix_scale(a, 1 + lmpar);
      gsl_matrix_add(a, cov);

      /* Solve A * x_step = b by means of Cholesky decomposition... */
      gsl_linalg_cholesky_decomp(a);
      gsl_linalg_cholesky_solve(a, b, x_step);

      /* Update atmospheric state... */
      gsl_vector_add(x_i, x_step);
      copy_atm(ctl, atm_i, atm_apr, 0);
      copy_obs(ctl, obs_i, obs_meas, 0);
      x2atm(ctl, x_i, atm_i);

      /* Check atmospheric state... */
      for (ip = 0; ip < atm_i->np; ip++) {
        atm_i->p[ip] = GSL_MIN(GSL_MAX(atm_i->p[ip], 5e-7), 5e4);
        atm_i->t[ip] = GSL_MIN(GSL_MAX(atm_i->t[ip], 100), 400);
        for (ig = 0; ig < ctl->ng; ig++)
          atm_i->q[ig][ip] = GSL_MIN(GSL_MAX(atm_i->q[ig][ip], 0), 1);
        for (iw = 0; iw < ctl->nw; iw++)
          atm_i->k[iw][ip] = GSL_MAX(atm_i->k[iw][ip], 0);
      }

      /* Forward calculation... */
      formod(ctl, atm_i, obs_i);
      obs2y(ctl, obs_i, y_i, NULL, NULL);

      /* Determine dx = x_i - x_a and dy = y - F(x_i) ... */
      gsl_vector_memcpy(dx, x_i);
      gsl_vector_sub(dx, x_a);
      gsl_vector_memcpy(dy, y_m);
      gsl_vector_sub(dy, y_i);

      /* Compute cost function... */
      chisq = cost_function(dx, dy, s_a_inv, sig_eps_inv);

      /* Modify Levenberg-Marquardt parameter... */
      if (chisq > chisq_old) {
        lmpar *= 10;
        gsl_vector_sub(x_i, x_step);
      } else {
        lmpar /= 10;
        break;
      }
    }

    /* Write info... */
    printf("it= %d / chi^2/m= %g\n", it, chisq);

    /* Write to cost function file... */
    fprintf(out, "%d %g %d %d\n", it, chisq, (int) m, (int) n);

    /* Get normalized step size in state space... */
    gsl_blas_ddot(x_step, b, &disq);
    disq /= (double) n;

    /* Convergence test... */
    if ((it == 1 || it % ret->kernel_recomp == 0) && disq < ret->
conv_dmin)
      break;
  }

  /* Close cost function file... */
  fclose(out);

  /* Store results... */
  write_atm(ret->dir, "atm_final.tab", ctl, atm_i);
  write_obs(ret->dir, "obs_final.tab", ctl, obs_i);
  write_matrix(ret->dir, "matrix_kernel.tab", ctl, k_i,
               atm_i, obs_i, "y", "x", "r");

  /* ------------------------------------------------------------
     Analysis of retrieval results...
     ------------------------------------------------------------ */

  /* Check if error analysis is requested... */
  if (ret->err_ana) {

    /* Allocate... */
    auxnm = gsl_matrix_alloc(n, m);
    corr = gsl_matrix_alloc(n, n);
    gain = gsl_matrix_alloc(n, m);

    /* Compute inverse retrieval covariance...
       cov^{-1} = S_a^{-1} + K_i^T * S_eps^{-1} * K_i */
    matrix_product(k_i, sig_eps_inv, 1, cov);
    gsl_matrix_add(cov, s_a_inv);

    /* Compute retrieval covariance... */
    matrix_invert(cov);
    write_matrix(ret->dir, "matrix_cov_ret.tab", ctl, cov,
                 atm_i, obs_i, "x", "x", "r");
    write_stddev("total", ret, ctl, atm_i, cov);

    /* Compute correlation matrix... */
    for (i = 0; i < n; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(corr, i, j, gsl_matrix_get(cov, i, j)
                       / sqrt(gsl_matrix_get(cov, i, i))
                       / sqrt(gsl_matrix_get(cov, j, j)));
    write_matrix(ret->dir, "matrix_corr.tab", ctl, corr,
                 atm_i, obs_i, "x", "x", "r");

    /* Compute gain matrix...
       G = cov * K^T * S_eps^{-1} */
    for (i = 0; i < n; i++)
      for (j = 0; j < m; j++)
        gsl_matrix_set(auxnm, i, j, gsl_matrix_get(k_i, j, i)
                       * gsl_pow_2(gsl_vector_get(sig_eps_inv, j)));
    gsl_blas_dgemm(CblasNoTrans, CblasNoTrans, 1.0, cov, auxnm, 0.0, gain);
    write_matrix(ret->dir, "matrix_gain.tab", ctl, gain,
                 atm_i, obs_i, "x", "y", "c");

    /* Compute retrieval error due to noise... */
    matrix_product(gain, sig_noise, 2, a);
    write_stddev("noise", ret, ctl, atm_i, a);

    /* Compute retrieval error  due to forward model errors... */
    matrix_product(gain, sig_formod, 2, a);
    write_stddev("formod", ret, ctl, atm_i, a);

    /* Compute averaging kernel matrix
       A = G * K ... */
    gsl_blas_dgemm(CblasNoTrans, CblasNoTrans, 1.0, gain, k_i, 0.0, a);
    write_matrix(ret->dir, "matrix_avk.tab", ctl, a,
                 atm_i, obs_i, "x", "x", "r");

    /* Analyze averaging kernel matrix... */
    analyze_avk(ret, ctl, atm_i, iqa, ipa, a);

    /* Free... */
    gsl_matrix_free(auxnm);
    gsl_matrix_free(corr);
    gsl_matrix_free(gain);
  }

  /* ------------------------------------------------------------
     Finalize...
     ------------------------------------------------------------ */

  gsl_matrix_free(a);
  gsl_matrix_free(cov);
  gsl_matrix_free(k_i);
  gsl_matrix_free(s_a_inv);

  gsl_vector_free(b);
  gsl_vector_free(dx);
  gsl_vector_free(dy);
  gsl_vector_free(sig_eps_inv);
  gsl_vector_free(sig_formod);
  gsl_vector_free(sig_noise);
  gsl_vector_free(x_a);
  gsl_vector_free(x_i);
  gsl_vector_free(x_step);
  gsl_vector_free(y_aux);
  gsl_vector_free(y_i);
  gsl_vector_free(y_m);
}
```

Here is the call graph for this function:



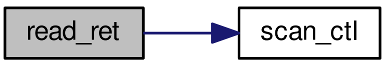
5.27.2.7 void read_ret (int *argc*, char ∗ *argv[ ]*, ctl_t ∗ *ctl*, ret_t ∗ *ret*)

Read retrieval control parameters.

Definition at line 730 of file retrieval.c.

```
               {

  int id, ig, iw;

  /* Iteration control... */
  ret->kernel_recomp =
    (int) scan_ctl(argc, argv, "KERNEL_RECOMP", -1, "3", NULL);
  ret->conv_itmax = (int) scan_ctl(argc, argv, "CONV_ITMAX", -1, "30", NULL);
  ret->conv_dmin = scan_ctl(argc, argv, "CONV_DMIN", -1, "0.1", NULL);

  /* Error analysis... */
  ret->err_ana = (int) scan_ctl(argc, argv, "ERR_ANA", -1, "1", NULL);

  for (id = 0; id < ctl->nd; id++)
    ret->err_formod[id] = scan_ctl(argc, argv, "ERR_FORMOD", id, "0", NULL);

  for (id = 0; id < ctl->nd; id++)
    ret->err_noise[id] = scan_ctl(argc, argv, "ERR_NOISE", id, "0", NULL);

  ret->err_press = scan_ctl(argc, argv, "ERR_PRESS", -1, "0", NULL);
  ret->err_press_cz = scan_ctl(argc, argv, "ERR_PRESS_CZ", -1, "-999", NULL);
  ret->err_press_ch = scan_ctl(argc, argv, "ERR_PRESS_CH", -1, "-999", NULL);

  ret->err_temp = scan_ctl(argc, argv, "ERR_TEMP", -1, "0", NULL);
  ret->err_temp_cz = scan_ctl(argc, argv, "ERR_TEMP_CZ", -1, "-999", NULL);
  ret->err_temp_ch = scan_ctl(argc, argv, "ERR_TEMP_CH", -1, "-999", NULL);

  for (ig = 0; ig < ctl->ng; ig++) {
    ret->err_q[ig] = scan_ctl(argc, argv, "ERR_Q", ig, "0", NULL);
    ret->err_q_cz[ig] = scan_ctl(argc, argv, "ERR_Q_CZ", ig, "-999", NULL);
    ret->err_q_ch[ig] = scan_ctl(argc, argv, "ERR_Q_CH", ig, "-999", NULL);
  }

  for (iw = 0; iw < ctl->nw; iw++) {
    ret->err_k[iw] = scan_ctl(argc, argv, "ERR_K", iw, "0", NULL);
    ret->err_k_cz[iw] = scan_ctl(argc, argv, "ERR_K_CZ", iw, "-999", NULL);
    ret->err_k_ch[iw] = scan_ctl(argc, argv, "ERR_K_CH", iw, "-999", NULL);
  }
}
```

Here is the call graph for this function:



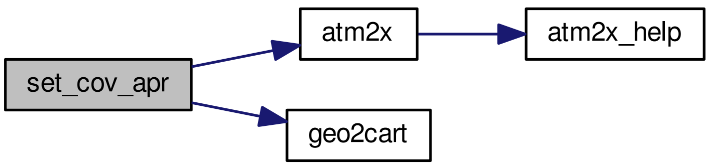
5.27.2.8 void set_cov_apr (ret_t * *ret,* ctl_t * *ctl,* atm_t * *atm,* int * *iqa,* int * *ipa,* gsl_matrix * *s_a*)

Set a priori covariance.

Definition at line 776 of file retrieval.c.

```
                     {

  gsl_vector *x_a;

  double ch, cz, rho, x0[3], x1[3];

  int ig, iw;

  size_t i, j, n;

  /* Get sizes... */
  n = s_a->size1;

  /* Allocate... */
  x_a = gsl_vector_alloc(n);

  /* Get sigma vector... */
  atm2x(ctl, atm, x_a, NULL, NULL);
  for (i = 0; i < n; i++) {
    if (iqa[i] == IDXP)
      gsl_vector_set(x_a, i, ret->err_press / 100 * gsl_vector_get(x_a, i));
    if (iqa[i] == IDXT)
      gsl_vector_set(x_a, i, ret->err_temp);
    for (ig = 0; ig < ctl->ng; ig++)
      if (iqa[i] == IDXQ(ig))
        gsl_vector_set(x_a, i, ret->err_q[ig] / 100 * gsl_vector_get(x_a, i));
    for (iw = 0; iw < ctl->nw; iw++)
      if (iqa[i] == IDXK(iw))
        gsl_vector_set(x_a, i, ret->err_k[iw]);
  }

  /* Check standard deviations... */
  for (i = 0; i < n; i++)
    if (gsl_pow_2(gsl_vector_get(x_a, i)) <= 0)
      ERRMSG("Check a priori data (zero standard deviation)!");

  /* Initialize diagonal covariance... */
  gsl_matrix_set_zero(s_a);
  for (i = 0; i < n; i++)
    gsl_matrix_set(s_a, i, i, gsl_pow_2(gsl_vector_get(x_a, i)));

  /* Loop over matrix elements... */
  for (i = 0; i < n; i++)
    for (j = 0; j < n; j++)
      if (i != j && iqa[i] == iqa[j]) {

        /* Initialize... */
        cz = ch = 0;

        /* Set correlation lengths for pressure... */
        if (iqa[i] == IDXP) {
          cz = ret->err_press_cz;
          ch = ret->err_press_ch;
        }

        /* Set correlation lengths for temperature... */
        if (iqa[i] == IDXT) {
          cz = ret->err_temp_cz;
          ch = ret->err_temp_ch;
        }

        /* Set correlation lengths for volume mixing ratios... */
        for (ig = 0; ig < ctl->ng; ig++)
          if (iqa[i] == IDXQ(ig)) {
            cz = ret->err_q_cz[ig];
            ch = ret->err_q_ch[ig];
          }

        /* Set correlation lengths for extinction... */
        for (iw = 0; iw < ctl->nw; iw++)
          if (iqa[i] == IDXK(iw)) {
            cz = ret->err_k_cz[iw];
            ch = ret->err_k_ch[iw];
          }

        /* Compute correlations... */
        if (cz > 0 && ch > 0) {

          /* Get Cartesian coordinates... */
          geo2cart(0, atm->lon[ipa[i]], atm->lat[ipa[i]], x0);
          geo2cart(0, atm->lon[ipa[j]], atm->lat[ipa[j]], x1);

          /* Compute correlations... */
          rho =
            exp(-DIST(x0, x1) / ch -
                fabs(atm->z[ipa[i]] - atm->z[ipa[j]]) / cz);

          /* Set covariance... */
          gsl_matrix_set(s_a, i, j, gsl_vector_get(x_a, i)
                         * gsl_vector_get(x_a, j) * rho);
        }
      }

  /* Free... */
  gsl_vector_free(x_a);
}
```

Here is the call graph for this function:



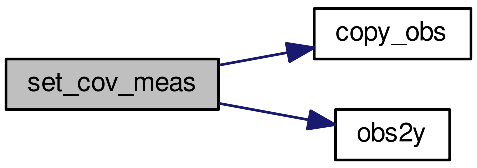
5.27.2.9 void set_cov_meas (ret_t * *ret*, ctl_t * *ctl*, obs_t * *obs*, gsl_vector * *sig_noise*, gsl_vector * *sig_formod*, gsl_vector * *sig_eps_inv*)

Set measurement errors.

Definition at line 881 of file retrieval.c.

```
                              {

  static obs_t obs_err;

  int id, ir;

  size_t i, m;

  /* Get size... */
  m = sig_eps_inv->size;

  /* Noise error (always considered in retrieval fit)... */
  copy_obs(ctl, &obs_err, obs, 1);
  for (ir = 0; ir < obs_err.nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      obs_err.rad[id][ir]
        = (gsl_finite(obs->rad[id][ir]) ? ret->err_noise[id] : GSL_NAN);
  obs2y(ctl, &obs_err, sig_noise, NULL, NULL);

  /* Forward model error (always considered in retrieval fit)... */
  copy_obs(ctl, &obs_err, obs, 1);
  for (ir = 0; ir < obs_err.nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      obs_err.rad[id][ir]
        = fabs(ret->err_formod[id] / 100 * obs->rad[id][ir]);
  obs2y(ctl, &obs_err, sig_formod, NULL, NULL);

  /* Total error... */
  for (i = 0; i < m; i++)
    gsl_vector_set(sig_eps_inv, i,
                   1 / sqrt(gsl_pow_2(gsl_vector_get(sig_noise, i))
                            + gsl_pow_2(gsl_vector_get(sig_formod, i))));

  /* Check standard deviations... */
  for (i = 0; i < m; i++)
    if (gsl_vector_get(sig_eps_inv, i) <= 0)
      ERRMSG("Check measurement errors (zero standard deviation)!");
}
```

Here is the call graph for this function:



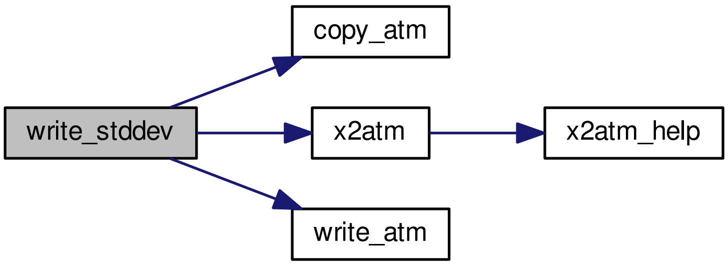
5.27.2.10 void write_stddev (const char * *quantity*, ret_t * *ret*, ctl_t * *ctl*, atm_t * *atm*, gsl_matrix * *s*)

Write retrieval error to file.

Definition at line 928 of file retrieval.c.

```
                 {

  static atm_t atm_aux;

  gsl_vector *x_aux;

  char filename[LEN];

  size_t i, n;

  /* Get sizes... */
  n = s->size1;

  /* Allocate... */
  x_aux = gsl_vector_alloc(n);

  /* Compute standard deviation... */
  for (i = 0; i < n; i++)
    gsl_vector_set(x_aux, i, sqrt(gsl_matrix_get(s, i, i)));

  /* Write to disk... */
  copy_atm(ctl, &atm_aux, atm, 1);
  x2atm(ctl, x_aux, &atm_aux);
  sprintf(filename, "atm_err_%s.tab", quantity);
  write_atm(ret->dir, filename, ctl, &atm_aux);

  /* Free... */
  gsl_vector_free(x_aux);
}
```

Here is the call graph for this function:

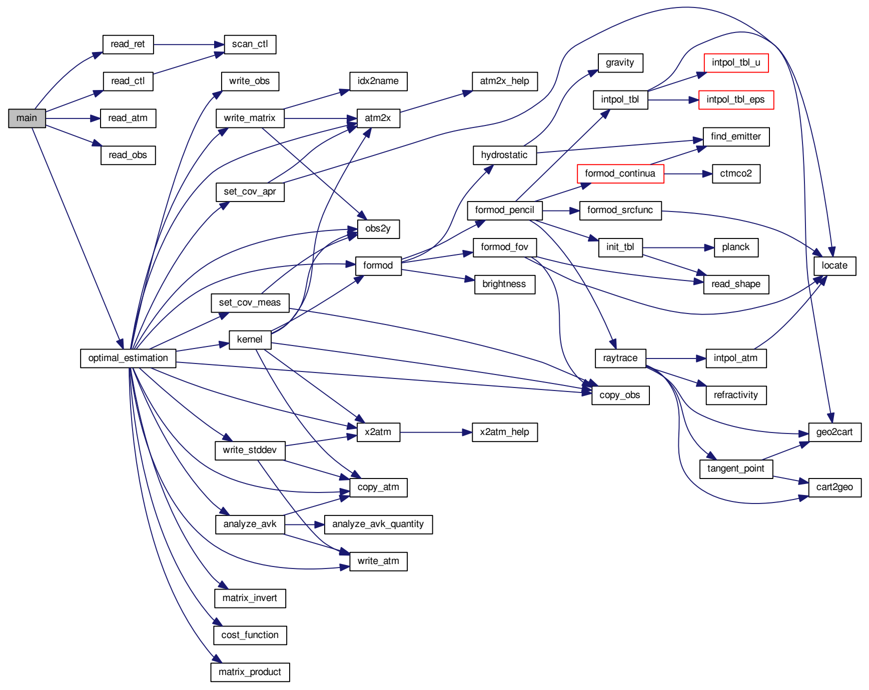


5.27.2.11 int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 180 of file retrieval.c.

```
                {

  static atm_t atm_i, atm_apr;
  static ctl_t ctl;
  static obs_t obs_i, obs_meas;
  static ret_t ret;

  FILE *dirlist;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <dirlist>");

  /* Measure CPU-time... */
  TIMER("total", 1);

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  read_ret(argc, argv, &ctl, &ret);

  /* Open directory list... */
  if (!(dirlist = fopen(argv[2], "r")))
    ERRMSG("Cannot open directory list!");

  /* Loop over directories... */
  while (fscanf(dirlist, "%s", ret.dir) != EOF) {

    /* Write info... */
    printf("\nRetrieve in directory %s...\n\n", ret.dir);

    /* Read atmospheric data... */
    read_atm(ret.dir, "atm_apr.tab", &ctl, &atm_apr);

    /* Read observation data... */
    read_obs(ret.dir, "obs_meas.tab", &ctl, &obs_meas);

    /* Run retrieval... */
    optimal_estimation(&ret, &ctl, &obs_meas, &obs_i, &atm_apr, &atm_i);

    /* Measure CPU-time... */
    TIMER("total", 2);
  }

  /* Write info... */
  printf("\nRetrieval done...\n");

  /* Measure CPU-time... */
  TIMER("total", 3);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.28 retrieval.c

```
/*
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  along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.

  Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
*/

#include "jurassic.h"

/* ------------------------------------------------------------
   Structs...
   ------------------------------------------------------------ */

typedef struct {

  char dir[LEN];

  int kernel_recomp;

  int conv_itmax;

  double conv_dmin;

  int err_ana;

  double err_formod[ND];

  double err_noise[ND];

  double err_press;

  double err_press_cz;

  double err_press_ch;

  double err_temp;

  double err_temp_cz;

  double err_temp_ch;

  double err_q[NG];

  double err_q_cz[NG];

  double err_q_ch[NG];

  double err_k[NW];

  double err_k_cz[NW];

  double err_k_ch[NW];

} ret_t;

/* ------------------------------------------------------------
   Functions...
   ------------------------------------------------------------ */

void analyze_avk(
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  int *iqa,
  int *ipa,
  gsl_matrix * avk);

void analyze_avk_quantity(
  gsl_matrix * avk,
  int iq,
  int *ipa,
  size_t * n0,
  size_t * n1,
  double *cont,
  double *res);

double cost_function(
  gsl_vector * dx,
  gsl_vector * dy,
  gsl_matrix * s_a_inv,
  gsl_vector * sig_eps_inv);

void matrix_invert(
  gsl_matrix * a);

void matrix_product(
  gsl_matrix * a,
  gsl_vector * b,
  int transpose,
  gsl_matrix * c);

void optimal_estimation(
  ret_t * ret,
  ctl_t * ctl,
  obs_t * obs_meas,
  obs_t * obs_i,
  atm_t * atm_apr,
  atm_t * atm_i);

void read_ret(
  int argc,
  char *argv[],
  ctl_t * ctl,
  ret_t * ret);

void set_cov_apr(
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  int *iqa,
  int *ipa,
  gsl_matrix * s_a);

void set_cov_meas(
  ret_t * ret,
  ctl_t * ctl,
  obs_t * obs,
  gsl_vector * sig_noise,
  gsl_vector * sig_formod,
  gsl_vector * sig_eps_inv);

void write_stddev(
  const char *quantity,
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  gsl_matrix * s);

/* ------------------------------------------------------------
   Main...
   ------------------------------------------------------------ */

int main(
  int argc,
  char *argv[]) {

  static atm_t atm_i, atm_apr;
  static ctl_t ctl;
  static obs_t obs_i, obs_meas;
  static ret_t ret;

  FILE *dirlist;

  /* Check arguments... */
  if (argc < 3)
    ERRMSG("Give parameters: <ctl> <dirlist>");

  /* Measure CPU-time... */
  TIMER("total", 1);

  /* Read control parameters... */
  read_ctl(argc, argv, &ctl);
  read_ret(argc, argv, &ctl, &ret);

  /* Open directory list... */
  if (!(dirlist = fopen(argv[2], "r")))
    ERRMSG("Cannot open directory list!");

  /* Loop over directories... */
  while (fscanf(dirlist, "%s", ret.dir) != EOF) {

    /* Write info... */
    printf("\nRetrieve in directory %s...\n\n", ret.dir);

    /* Read atmospheric data... */
    read_atm(ret.dir, "atm_apr.tab", &ctl, &atm_apr);

    /* Read observation data... */
    read_obs(ret.dir, "obs_meas.tab", &ctl, &obs_meas);

    /* Run retrieval... */
    optimal_estimation(&ret, &ctl, &obs_meas, &obs_i, &atm_apr, &atm_i);

    /* Measure CPU-time... */
    TIMER("total", 2);
  }

  /* Write info... */
  printf("\nRetrieval done...\n");

  /* Measure CPU-time... */
  TIMER("total", 3);

  return EXIT_SUCCESS;
}

/*****************************************************************************/

void analyze_avk(
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  int *iqa,
  int *ipa,
  gsl_matrix * avk) {

  static atm_t atm_cont, atm_res;

  int ig, iq, iw;

  size_t i, n, n0[NQ], n1[NQ];

  /* Get sizes... */
  n = avk->size1;

  /* Find sub-matrices for different quantities... */
  for (iq = 0; iq < NQ; iq++) {
    n0[iq] = N;
    for (i = 0; i < n; i++) {
      if (iqa[i] == iq && n0[iq] == N)
        n0[iq] = i;
      if (iqa[i] == iq)
        n1[iq] = i - n0[iq] + 1;
    }
  }

  /* Initialize... */
  copy_atm(ctl, &atm_cont, atm, 1);
  copy_atm(ctl, &atm_res, atm, 1);

  /* Analyze quantities... */
  analyze_avk_quantity(avk, IDXP, ipa, n0, n1, atm_cont.p, atm_res.
p);
  analyze_avk_quantity(avk, IDXT, ipa, n0, n1, atm_cont.t, atm_res.
t);
  for (ig = 0; ig < ctl->ng; ig++)
    analyze_avk_quantity(avk, IDXQ(ig), ipa, n0, n1,
                         atm_cont.q[ig], atm_res.q[ig]);
  for (iw = 0; iw < ctl->nw; iw++)
    analyze_avk_quantity(avk, IDXK(iw), ipa, n0, n1,
                         atm_cont.k[iw], atm_res.k[iw]);

  /* Write results to disk... */
  write_atm(ret->dir, "atm_cont.tab", ctl, &atm_cont);
  write_atm(ret->dir, "atm_res.tab", ctl, &atm_res);
}

/*****************************************************************************/

void analyze_avk_quantity(
  gsl_matrix * avk,
  int iq,
  int *ipa,
  size_t * n0,
  size_t * n1,
  double *cont,
  double *res) {

  size_t i, j;

  /* Loop over state vector elements... */
  if (n0[iq] < N)
    for (i = 0; i < n1[iq]; i++) {

      /* Get area of averagig kernel... */
      for (j = 0; j < n1[iq]; j++)
        cont[ipa[n0[iq] + i]] += gsl_matrix_get(avk, n0[iq] + i, n0[iq] + j);

      /* Get information density... */
      res[ipa[n0[iq] + i]] = 1 / gsl_matrix_get(avk, n0[iq] + i, n0[iq] + i);
    }
}

/*****************************************************************************/

double cost_function(
  gsl_vector * dx,
  gsl_vector * dy,
  gsl_matrix * s_a_inv,
  gsl_vector * sig_eps_inv) {

  gsl_vector *x_aux, *y_aux;

  double chisq_a, chisq_m = 0;

  size_t i, m, n;

  /* Get sizes... */
  m = dy->size;
  n = dx->size;

  /* Allocate... */
  x_aux = gsl_vector_alloc(n);
  y_aux = gsl_vector_alloc(m);

  /* Determine normalized cost function...
     (chi^2 = 1/m * [dy^T * S_eps^{-1} * dy + dx^T * S_a^{-1} * dx]) */
  for (i = 0; i < m; i++)
    chisq_m +=
      gsl_pow_2(gsl_vector_get(dy, i) * gsl_vector_get(sig_eps_inv, i));
  gsl_blas_dgemv(CblasNoTrans, 1.0, s_a_inv, dx, 0.0, x_aux);
  gsl_blas_ddot(dx, x_aux, &chisq_a);

  /* Free... */
  gsl_vector_free(x_aux);
  gsl_vector_free(y_aux);

  /* Return cost function value... */
  return (chisq_m + chisq_a) / (double) m;
}

/*****************************************************************************/

void matrix_invert(
  gsl_matrix * a) {

  size_t diag = 1, i, j, n;

  /* Get size... */
  n = a->size1;

  /* Check if matrix is diagonal... */
  for (i = 0; i < n && diag; i++)
    for (j = i + 1; j < n; j++)
      if (gsl_matrix_get(a, i, j) != 0) {
        diag = 0;
        break;
      }

  /* Quick inversion of diagonal matrix... */
  if (diag)
    for (i = 0; i < n; i++)
      gsl_matrix_set(a, i, i, 1 / gsl_matrix_get(a, i, i));

  /* Matrix inversion by means of Cholesky decomposition... */
  else {
    gsl_linalg_cholesky_decomp(a);
    gsl_linalg_cholesky_invert(a);
  }
}

/*****************************************************************************/

void matrix_product(
  gsl_matrix * a,
  gsl_vector * b,
  int transpose,
  gsl_matrix * c) {

  gsl_matrix *aux;

  size_t i, j, m, n;

  /* Set sizes... */
  m = a->size1;
  n = a->size2;

  /* Allocate... */
  aux = gsl_matrix_alloc(m, n);

  /* Compute A^T B A... */
  if (transpose == 1) {

    /* Compute B^1/2 A... */
    for (i = 0; i < m; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(aux, i, j,
                       gsl_vector_get(b, i) * gsl_matrix_get(a, i, j));

    /* Compute A^T B A = (B^1/2 A)^T (B^1/2 A)... */
    gsl_blas_dgemm(CblasTrans, CblasNoTrans, 1.0, aux, aux, 0.0, c);
  }

  /* Compute A B A^T... */
  else if (transpose == 2) {

    /* Compute A B^1/2... */
    for (i = 0; i < m; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(aux, i, j,
                       gsl_matrix_get(a, i, j) * gsl_vector_get(b, j));

    /* Compute A B A^T = (A B^1/2) (A B^1/2)^T... */
    gsl_blas_dgemm(CblasNoTrans, CblasTrans, 1.0, aux, aux, 0.0, c);
  }

  /* Free... */
  gsl_matrix_free(aux);
}

/*****************************************************************************/

void optimal_estimation(
  ret_t * ret,
  ctl_t * ctl,
  obs_t * obs_meas,
  obs_t * obs_i,
  atm_t * atm_apr,
  atm_t * atm_i) {

  static int ipa[N], iqa[N];

  gsl_matrix *a, *auxnm, *corr, *cov, *gain, *k_i, *s_a_inv;
  gsl_vector *b, *dx, *dy, *sig_eps_inv, *sig_formod, *sig_noise,
    *x_a, *x_i, *x_step, *y_aux, *y_i, *y_m;

  FILE *out;

  char filename[LEN];

  double chisq, chisq_old, disq = 0, lmpar = 0.001;

  int ig, ip, it = 0, it2, iw;

  size_t i, j, m, n;

  /* ------------------------------------------------------------
     Initialize...
     ------------------------------------------------------------ */

  /* Get sizes... */
  m = obs2y(ctl, obs_meas, NULL, NULL, NULL);
  n = atm2x(ctl, atm_apr, NULL, iqa, ipa);
  if (m <= 0 || n <= 0)
    ERRMSG("Check problem definition!");

  /* Write info... */
  printf("Problem size: m= %d / n= %d "
         "(alloc= %.4g MB / stat= %.4g MB)\n",
         (int) m, (int) n,
         (double) (3 * m * n + 4 * n * n + 8 * m +
                   8 * n) * sizeof(double) / 1024. / 1024.,
         (double) (5 * sizeof(atm_t) + 3 * sizeof(obs_t)
                   + 2 * N * sizeof(int)) / 1024. / 1024.);

  /* Allocate... */
  a = gsl_matrix_alloc(n, n);
  cov = gsl_matrix_alloc(n, n);
  k_i = gsl_matrix_alloc(m, n);
  s_a_inv = gsl_matrix_alloc(n, n);

  b = gsl_vector_alloc(n);
  dx = gsl_vector_alloc(n);
  dy = gsl_vector_alloc(m);
  sig_eps_inv = gsl_vector_alloc(m);
  sig_formod = gsl_vector_alloc(m);
  sig_noise = gsl_vector_alloc(m);
  x_a = gsl_vector_alloc(n);
  x_i = gsl_vector_alloc(n);
  x_step = gsl_vector_alloc(n);
  y_aux = gsl_vector_alloc(m);
  y_i = gsl_vector_alloc(m);
  y_m = gsl_vector_alloc(m);

  /* Set initial state... */
  copy_atm(ctl, atm_i, atm_apr, 0);
  copy_obs(ctl, obs_i, obs_meas, 0);
  formod(ctl, atm_i, obs_i);

  /* Set state vectors and observation vectors... */
  atm2x(ctl, atm_apr, x_a, NULL, NULL);
  atm2x(ctl, atm_i, x_i, NULL, NULL);
  obs2y(ctl, obs_meas, y_m, NULL, NULL);
  obs2y(ctl, obs_i, y_i, NULL, NULL);

  /* Set inverse a priori covariance S_a^-1... */
  set_cov_apr(ret, ctl, atm_apr, iqa, ipa, s_a_inv);
  write_matrix(ret->dir, "matrix_cov_apr.tab", ctl, s_a_inv,
               atm_i, obs_i, "x", "x", "r");
  matrix_invert(s_a_inv);

  /* Get measurement errors... */
  set_cov_meas(ret, ctl, obs_meas, sig_noise, sig_formod, sig_eps_inv);

  /* Create cost function file... */
  sprintf(filename, "%s/costs.tab", ret->dir);
  if (!(out = fopen(filename, "w")))
    ERRMSG("Cannot create cost function file!");

  /* Write header... */
  fprintf(out,
          "# $1 = iteration number\n"
          "# $2 = normalized cost function\n"
          "# $3 = number of measurements\n"
          "# $4 = number of state vector elements\n\n");

  /* Determine dx = x_i - x_a and dy = y - F(x_i) ... */
  gsl_vector_memcpy(dx, x_i);
  gsl_vector_sub(dx, x_a);
  gsl_vector_memcpy(dy, y_m);
  gsl_vector_sub(dy, y_i);

  /* Compute cost function... */
  chisq = cost_function(dx, dy, s_a_inv, sig_eps_inv);

  /* Write info... */
  printf("it= %d / chi^2/m= %g\n", it, chisq);

  /* Write to cost function file... */
  fprintf(out, "%d %g %d %d\n", it, chisq, (int) m, (int) n);

  /* Compute initial kernel... */
  kernel(ctl, atm_i, obs_i, k_i);

  /* ------------------------------------------------------------
     Levenberg-Marquardt minimization...
     ------------------------------------------------------------ */

  /* Outer loop... */
  for (it = 1; it <= ret->conv_itmax; it++) {

    /* Store current cost function value... */
    chisq_old = chisq;

    /* Compute kernel matrix K_i... */
    if (it > 1 && it % ret->kernel_recomp == 0)
      kernel(ctl, atm_i, obs_i, k_i);

    /* Compute K_i^T * S_eps^{-1} * K_i ... */
    if (it == 1 || it % ret->kernel_recomp == 0)
      matrix_product(k_i, sig_eps_inv, 1, cov);

    /* Determine b = K_i^T * S_eps^{-1} * dy - S_a^{-1} * dx ... */
    for (i = 0; i < m; i++)
```

```
      gsl_vector_set(y_aux, i, gsl_vector_get(dy, i)
                    * gsl_pow_2(gsl_vector_get(sig_eps_inv, i)));
    gsl_blas_dgemv(CblasTrans, 1.0, k_i, y_aux, 0.0, b);
    gsl_blas_dgemv(CblasNoTrans, -1.0, s_a_inv, dx, 1.0, b);

    /* Inner loop... */
    for (it2 = 0; it2 < 20; it2++) {

      /* Compute A = (1 + lmpar) * S_a^{-1} + K_i^T * S_eps^{-1} * K_i ... */
      gsl_matrix_memcpy(a, s_a_inv);
      gsl_matrix_scale(a, 1 + lmpar);
      gsl_matrix_add(a, cov);

      /* Solve A * x_step = b by means of Cholesky decomposition... */
      gsl_linalg_cholesky_decomp(a);
      gsl_linalg_cholesky_solve(a, b, x_step);

      /* Update atmospheric state... */
      gsl_vector_add(x_i, x_step);
      copy_atm(ctl, atm_i, atm_apr, 0);
      copy_obs(ctl, obs_i, obs_meas, 0);
      x2atm(ctl, x_i, atm_i);

      /* Check atmospheric state... */
      for (ip = 0; ip < atm_i->np; ip++) {
        atm_i->p[ip] = GSL_MIN(GSL_MAX(atm_i->p[ip], 5e-7), 5e4);
        atm_i->t[ip] = GSL_MIN(GSL_MAX(atm_i->t[ip], 100), 400);
        for (ig = 0; ig < ctl->ng; ig++)
          atm_i->q[ig][ip] = GSL_MIN(GSL_MAX(atm_i->q[ig][ip], 0), 1);
        for (iw = 0; iw < ctl->nw; iw++)
          atm_i->k[iw][ip] = GSL_MAX(atm_i->k[iw][ip], 0);
      }

      /* Forward calculation... */
      formod(ctl, atm_i, obs_i);
      obs2y(ctl, obs_i, y_i, NULL, NULL);

      /* Determine dx = x_i - x_a and dy = y - F(x_i) ... */
      gsl_vector_memcpy(dx, x_i);
      gsl_vector_sub(dx, x_a);
      gsl_vector_memcpy(dy, y_m);
      gsl_vector_sub(dy, y_i);

      /* Compute cost function... */
      chisq = cost_function(dx, dy, s_a_inv, sig_eps_inv);

      /* Modify Levenberg-Marquardt parameter... */
      if (chisq > chisq_old) {
        lmpar *= 10;
        gsl_vector_sub(x_i, x_step);
      } else {
        lmpar /= 10;
        break;
      }
    }

    /* Write info... */
    printf("it= %d / chi^2/m= %g\n", it, chisq);

    /* Write to cost function file... */
    fprintf(out, "%d %g %d %d\n", it, chisq, (int) m, (int) n);

    /* Get normalized step size in state space... */
    gsl_blas_ddot(x_step, b, &disq);
    disq /= (double) n;

    /* Convergence test... */
    if ((it == 1 || it % ret->kernel_recomp == 0) && disq < ret->
conv_dmin)
      break;
  }

  /* Close cost function file... */
  fclose(out);

  /* Store results... */
  write_atm(ret->dir, "atm_final.tab", ctl, atm_i);
  write_obs(ret->dir, "obs_final.tab", ctl, obs_i);
  write_matrix(ret->dir, "matrix_kernel.tab", ctl, k_i,
               atm_i, obs_i, "y", "x", "r");

  /* ------------------------------------------------------------
     Analysis of retrieval results...
     ------------------------------------------------------------ */

  /* Check if error analysis is requested... */
  if (ret->err_ana) {

    /* Allocate... */
    auxnm = gsl_matrix_alloc(n, m);
    corr = gsl_matrix_alloc(n, n);
    gain = gsl_matrix_alloc(n, m);

    /* Compute inverse retrieval covariance...
       cov^{-1} = S_a^{-1} + K_i^T * S_eps^{-1} * K_i */
    matrix_product(k_i, sig_eps_inv, 1, cov);
    gsl_matrix_add(cov, s_a_inv);

    /* Compute retrieval covariance... */
    matrix_invert(cov);
    write_matrix(ret->dir, "matrix_cov_ret.tab", ctl, cov,
                 atm_i, obs_i, "x", "x", "r");
    write_stddev("total", ret, ctl, atm_i, cov);

    /* Compute correlation matrix... */
    for (i = 0; i < n; i++)
      for (j = 0; j < n; j++)
        gsl_matrix_set(corr, i, j, gsl_matrix_get(cov, i, j)
                       / sqrt(gsl_matrix_get(cov, i, i))
                       / sqrt(gsl_matrix_get(cov, j, j)));
    write_matrix(ret->dir, "matrix_corr.tab", ctl, corr,
                 atm_i, obs_i, "x", "x", "r");

    /* Compute gain matrix...
       G = cov * K^T * S_eps^{-1} */
    for (i = 0; i < n; i++)
      for (j = 0; j < m; j++)
        gsl_matrix_set(auxnm, i, j, gsl_matrix_get(k_i, j, i)
                       * gsl_pow_2(gsl_vector_get(sig_eps_inv, j)));
    gsl_blas_dgemm(CblasNoTrans, CblasNoTrans, 1.0, cov, auxnm, 0.0, gain);
    write_matrix(ret->dir, "matrix_gain.tab", ctl, gain,
                 atm_i, obs_i, "x", "y", "c");

    /* Compute retrieval error due to noise... */
    matrix_product(gain, sig_noise, 2, a);
    write_stddev("noise", ret, ctl, atm_i, a);

    /* Compute retrieval error  due to forward model errors... */
    matrix_product(gain, sig_formod, 2, a);
    write_stddev("formod", ret, ctl, atm_i, a);

    /* Compute averaging kernel matrix
       A = G * K ... */
    gsl_blas_dgemm(CblasNoTrans, CblasNoTrans, 1.0, gain, k_i, 0.0, a);
    write_matrix(ret->dir, "matrix_avk.tab", ctl, a,
                 atm_i, obs_i, "x", "x", "r");

    /* Analyze averaging kernel matrix... */
    analyze_avk(ret, ctl, atm_i, iqa, ipa, a);

    /* Free... */
    gsl_matrix_free(auxnm);
    gsl_matrix_free(corr);
    gsl_matrix_free(gain);
  }

  /* ------------------------------------------------------------
     Finalize...
     ------------------------------------------------------------ */

  gsl_matrix_free(a);
  gsl_matrix_free(cov);
  gsl_matrix_free(k_i);
  gsl_matrix_free(s_a_inv);

  gsl_vector_free(b);
  gsl_vector_free(dx);
  gsl_vector_free(dy);
  gsl_vector_free(sig_eps_inv);
  gsl_vector_free(sig_formod);
  gsl_vector_free(sig_noise);
  gsl_vector_free(x_a);
  gsl_vector_free(x_i);
  gsl_vector_free(x_step);
  gsl_vector_free(y_aux);
  gsl_vector_free(y_i);
  gsl_vector_free(y_m);
}

/*****************************************************************************/

void read_ret(
  int argc,
  char *argv[],
  ctl_t * ctl,
  ret_t * ret) {

  int id, ig, iw;

  /* Iteration control... */
  ret->kernel_recomp =
    (int) scan_ctl(argc, argv, "KERNEL_RECOMP", -1, "3", NULL);
  ret->conv_itmax = (int) scan_ctl(argc, argv, "CONV_ITMAX", -1, "30", NULL);
  ret->conv_dmin = scan_ctl(argc, argv, "CONV_DMIN", -1, "0.1", NULL);

  /* Error analysis... */
  ret->err_ana = (int) scan_ctl(argc, argv, "ERR_ANA", -1, "1", NULL);

  for (id = 0; id < ctl->nd; id++)
    ret->err_formod[id] = scan_ctl(argc, argv, "ERR_FORMOD", id, "0", NULL);

  for (id = 0; id < ctl->nd; id++)
    ret->err_noise[id] = scan_ctl(argc, argv, "ERR_NOISE", id, "0", NULL);

  ret->err_press = scan_ctl(argc, argv, "ERR_PRESS", -1, "0", NULL);
  ret->err_press_cz = scan_ctl(argc, argv, "ERR_PRESS_CZ", -1, "-999", NULL);
  ret->err_press_ch = scan_ctl(argc, argv, "ERR_PRESS_CH", -1, "-999", NULL);

  ret->err_temp = scan_ctl(argc, argv, "ERR_TEMP", -1, "0", NULL);
  ret->err_temp_cz = scan_ctl(argc, argv, "ERR_TEMP_CZ", -1, "-999", NULL);
  ret->err_temp_ch = scan_ctl(argc, argv, "ERR_TEMP_CH", -1, "-999", NULL);

  for (ig = 0; ig < ctl->ng; ig++) {
    ret->err_q[ig] = scan_ctl(argc, argv, "ERR_Q", ig, "0", NULL);
    ret->err_q_cz[ig] = scan_ctl(argc, argv, "ERR_Q_CZ", ig, "-999", NULL);
    ret->err_q_ch[ig] = scan_ctl(argc, argv, "ERR_Q_CH", ig, "-999", NULL);
  }

  for (iw = 0; iw < ctl->nw; iw++) {
    ret->err_k[iw] = scan_ctl(argc, argv, "ERR_K", iw, "0", NULL);
    ret->err_k_cz[iw] = scan_ctl(argc, argv, "ERR_K_CZ", iw, "-999", NULL);
    ret->err_k_ch[iw] = scan_ctl(argc, argv, "ERR_K_CH", iw, "-999", NULL);
  }
}

/*****************************************************************************/

void set_cov_apr(
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  int *iqa,
  int *ipa,
  gsl_matrix * s_a) {

  gsl_vector *x_a;

  double ch, cz, rho, x0[3], x1[3];

  int ig, iw;

  size_t i, j, n;

  /* Get sizes... */
  n = s_a->size1;

  /* Allocate... */
  x_a = gsl_vector_alloc(n);

  /* Get sigma vector... */
  atm2x(ctl, atm, x_a, NULL, NULL);
  for (i = 0; i < n; i++) {
    if (iqa[i] == IDXP)
      gsl_vector_set(x_a, i, ret->err_press / 100 * gsl_vector_get(x_a, i));
    if (iqa[i] == IDXT)
      gsl_vector_set(x_a, i, ret->err_temp);
    for (ig = 0; ig < ctl->ng; ig++)
      if (iqa[i] == IDXQ(ig))
        gsl_vector_set(x_a, i, ret->err_q[ig] / 100 * gsl_vector_get(x_a, i));
    for (iw = 0; iw < ctl->nw; iw++)
      if (iqa[i] == IDXK(iw))
        gsl_vector_set(x_a, i, ret->err_k[iw]);
  }

  /* Check standard deviations... */
  for (i = 0; i < n; i++)
    if (gsl_pow_2(gsl_vector_get(x_a, i)) <= 0)
      ERRMSG("Check a priori data (zero standard deviation)!");

  /* Initialize diagonal covariance... */
  gsl_matrix_set_zero(s_a);
  for (i = 0; i < n; i++)
    gsl_matrix_set(s_a, i, i, gsl_pow_2(gsl_vector_get(x_a, i)));

  /* Loop over matrix elements... */
  for (i = 0; i < n; i++)
    for (j = 0; j < n; j++)
      if (i != j && iqa[i] == iqa[j]) {

        /* Initialize... */
        cz = ch = 0;

        /* Set correlation lengths for pressure... */
        if (iqa[i] == IDXP) {
          cz = ret->err_press_cz;
          ch = ret->err_press_ch;
        }

        /* Set correlation lengths for temperature... */
        if (iqa[i] == IDXT) {
          cz = ret->err_temp_cz;
          ch = ret->err_temp_ch;
        }

        /* Set correlation lengths for volume mixing ratios... */
        for (ig = 0; ig < ctl->ng; ig++)
          if (iqa[i] == IDXQ(ig)) {
            cz = ret->err_q_cz[ig];
            ch = ret->err_q_ch[ig];
          }

        /* Set correlation lengths for extinction... */
        for (iw = 0; iw < ctl->nw; iw++)
          if (iqa[i] == IDXK(iw)) {
            cz = ret->err_k_cz[iw];
            ch = ret->err_k_ch[iw];
          }

        /* Compute correlations... */
        if (cz > 0 && ch > 0) {

          /* Get Cartesian coordinates... */
          geo2cart(0, atm->lon[ipa[i]], atm->lat[ipa[i]], x0);
          geo2cart(0, atm->lon[ipa[j]], atm->lat[ipa[j]], x1);

          /* Compute correlations... */
          rho =
            exp(-DIST(x0, x1) / ch -
                fabs(atm->z[ipa[i]] - atm->z[ipa[j]]) / cz);

          /* Set covariance... */
          gsl_matrix_set(s_a, i, j, gsl_vector_get(x_a, i)
                         * gsl_vector_get(x_a, j) * rho);
        }
      }

  /* Free... */
  gsl_vector_free(x_a);
}

/*****************************************************************************/

void set_cov_meas(
  ret_t * ret,
  ctl_t * ctl,
  obs_t * obs,
  gsl_vector * sig_noise,
  gsl_vector * sig_formod,
  gsl_vector * sig_eps_inv) {

  static obs_t obs_err;

  int id, ir;

  size_t i, m;

  /* Get size... */
  m = sig_eps_inv->size;

  /* Noise error (always considered in retrieval fit)... */
  copy_obs(ctl, &obs_err, obs, 1);
  for (ir = 0; ir < obs_err.nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      obs_err.rad[id][ir]
        = (gsl_finite(obs->rad[id][ir]) ? ret->err_noise[id] : GSL_NAN);
  obs2y(ctl, &obs_err, sig_noise, NULL, NULL);

  /* Forward model error (always considered in retrieval fit)... */
  copy_obs(ctl, &obs_err, obs, 1);
  for (ir = 0; ir < obs_err.nr; ir++)
    for (id = 0; id < ctl->nd; id++)
      obs_err.rad[id][ir]
        = fabs(ret->err_formod[id] / 100 * obs->rad[id][ir]);
  obs2y(ctl, &obs_err, sig_formod, NULL, NULL);

  /* Total error... */
  for (i = 0; i < m; i++)
    gsl_vector_set(sig_eps_inv, i,
                   1 / sqrt(gsl_pow_2(gsl_vector_get(sig_noise, i))
                            + gsl_pow_2(gsl_vector_get(sig_formod, i))));

  /* Check standard deviations... */
  for (i = 0; i < m; i++)
    if (gsl_vector_get(sig_eps_inv, i) <= 0)
      ERRMSG("Check measurement errors (zero standard deviation)!");
}

/*****************************************************************************/

void write_stddev(
  const char *quantity,
  ret_t * ret,
  ctl_t * ctl,
  atm_t * atm,
  gsl_matrix * s) {

  static atm_t atm_aux;

  gsl_vector *x_aux;

  char filename[LEN];

  size_t i, n;

  /* Get sizes... */
  n = s->size1;

  /* Allocate... */
  x_aux = gsl_vector_alloc(n);

  /* Compute standard deviation... */
  for (i = 0; i < n; i++)
    gsl_vector_set(x_aux, i, sqrt(gsl_matrix_get(s, i, i)));

  /* Write to disk... */
  copy_atm(ctl, &atm_aux, atm, 1);
  x2atm(ctl, x_aux, &atm_aux);
  sprintf(filename, "atm_err_%s.tab", quantity);
  write_atm(ret->dir, filename, ctl, &atm_aux);

  /* Free... */
  gsl_vector_free(x_aux);
}
```

5.29 time2jsec.c File Reference

Convert date to Julian seconds.

Functions

- int main (int argc, char *argv[ ])

5.29.1 Detailed Description

Convert date to Julian seconds.

Definition in file time2jsec.c.

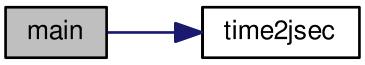
5.29.2 Function Documentation

5.29.2.1 int main (int *argc*, char ∗ *argv[ ]*)

Definition at line 27 of file time2jsec.c.

```
                  {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 8)
    ERRMSG("Give parameters: <year> <mon> <day> <hour> <min> <sec> <remain>");

  /* Read arguments... */
  year = atoi(argv[1]);
  mon = atoi(argv[2]);
  day = atoi(argv[3]);
  hour = atoi(argv[4]);
  min = atoi(argv[5]);
  sec = atoi(argv[6]);
  remain = atof(argv[7]);

  /* Convert... */
  time2jsec(year, mon, day, hour, min, sec, remain, &jsec);
  printf("%.2f\n", jsec);

  return EXIT_SUCCESS;
}
```

Here is the call graph for this function:



5.30 time2jsec.c

```
00001 /*
00002   This file is part of JURASSIC.
00003
00004   JURASSIC is free software: you can redistribute it and/or modify
00005   it under the terms of the GNU General Public License as published by
00006   the Free Software Foundation, either version 3 of the License, or
00007   (at your option) any later version.
00008
00009   JURASSIC is distributed in the hope that it will be useful,
00010   but WITHOUT ANY WARRANTY; without even the implied warranty of
00011   MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the
00012   GNU General Public License for more details.
00013
00014   You should have received a copy of the GNU General Public License
00015   along with JURASSIC. If not, see <http://www.gnu.org/licenses/>.
00016
00017   Copright (C) 2003-2015 Forschungszentrum Juelich GmbH
00018 */
00019
00025 #include "jurassic.h"
00026
00027 int main(
00028   int argc,
00029   char *argv[]) {

  double jsec, remain;

  int day, hour, min, mon, sec, year;

  /* Check arguments... */
  if (argc < 8)
    ERRMSG("Give parameters: <year> <mon> <day> <hour> <min> <sec> <remain>");

  /* Read arguments... */
  year = atoi(argv[1]);
  mon = atoi(argv[2]);
  day = atoi(argv[3]);
  hour = atoi(argv[4]);
  min = atoi(argv[5]);
  sec = atoi(argv[6]);
  remain = atof(argv[7]);

  /* Convert... */
  time2jsec(year, mon, day, hour, min, sec, remain, &jsec);
  printf("%.2f\n", jsec);

  return EXIT_SUCCESS;
}
```

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